Rethinking Monetary Policy:

Towards Higher Inflation Expectations in the Aftermath of the Global Financial Crisis

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Abstract

This thesis rethinks monetary policy dividing time into two review-contexts in relation to the recent global financial crisis. The thesis leans on three different theoretical and quantitative models which are applied in order to examine a central bank's possibilities to control or affect inflation. The first review-context covers time from post-WWII to the end of the period of Great Moderation, which preceded the crisis. The second review-context covers time from the eruption of the crisis in 2008 to the current day.

The thesis is motivated by several questions. First of all, the thesis aims to examine the fundamental differences in monetary policy between the pre and the post-crisis periods, i.e. to examine the differences between conventional and unconventional monetary policies. Secondly, the thesis attempts to examine what possibilities are available to a central bank in controlling inflation in different schemes and within both contexts. Thirdly, as the inflation rate is persistently low in the eurozone this thesis endeavors to explain and provide suggestions to create higher inflation expectations and potential options to escape a liquidity trap situation.

In the pre-crisis context it was found that the coordination of monetary and fiscal policies play a key role considering a central bank's possibilities to control or affect inflation. It was also found, whitin another model, that a central bank is able to control inflation (and expectations) by choosing and credibly following a policy rule. With the examination of the central and commercial banks' balance sheets and credit creation it was observed that deposits and reserves have a crucial role in the monetary system.

In the post-crisis context it was found that, even if the zero lower bound on the nominal interest rate is binding and further causing conventional open market operations to be ineffective, the central bank may stimulate the economy via quantitative easing. By these unconventional open market operations the central bank extends credit to the economy, provides more liquid assets to the private sector in the form of reserves and government debt, and is able to show commitment to change to another monetary policy rule that is associated with higher inflation expectations. Evidence from the swap market data was found to support the claim that long-term asset purchases and thereby expanded central bank balance sheets succeeded in increasing inflation expectations in the USA and in the UK in the midst of the crisis. The thesis introduces also an unwelcome liquidity trap situation in monetary policy, where the nominal interest rate hits the (zero) lower bound and cannot be lowered further. Potential solutions to escape the trap are discussed.

Keywords

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Tiivistelmä

Tutkielma tarkastelee rahapolitiikkaa globaalin finanssikriisin jälkimainingeissa jakaen ajan kahteen eri tarkastelujaksoon. Tutkielma nojaa kolmeen eri teoreettiseen ja kvantitatiiviseen malliin, joita sovelletaan pyrittäessä tutkimaan keskuspankin mahdollisuuksia kontrolloida inflaatiota tai vaikuttaa siihen. Ensimmäinen tarkastelujakso käsittää ajan Toisesta maailmansodasta “Great Moderation” –nimellä kutsuttavan ajanjakson loppuun, joka edelsi kriisiä. Jälkimmäinen tarkastelujakso käsittää ajan kriisin puhkeamisesta vuonna 2008 nykypäivään.

Tutkielman aihetta motivoivat seuraavat kysymykset. Ensinnäkin, tutkielma pyrkii selvittämään perustavanlaatuiset erot rahapolitiikassa kriisiä edeltävässä ja sen jälkeisessä ajanjaksossa; toisin sanoen selvittämään tavanomaisen ja epätavanomaisen rahapolitiikan erot. Toiseksi, tutkielma tarkastelee keskuspankin käytettävissä olevia mahdollisuuksia kontrolloida inflaatiota eri koordinaatiokehyksissä ja molemmissa ajanjaksoissa. Tämän lisäksi, inflaation ollessa sitkeästi alhaisella tasolla euroalueella, tutkielma pyrkii esittämään mahdollisuuksia luoda korkeampia inflaatio-odotuksia ja potentiaalisia vaihtoehtoja päästä pois nk. likviditeettiloukusta.

Kriisiä edeltävässä tarkastelujaksossa raha- ja finanssipolitiikan kordinaatiolla havaittiin olevan keskeinen rooli ajatellen keskuspankkien mahdollisuuksia kontrolloida tai vaikuttaa inflaatioon. Todettiin myös, toisen mallin puitteissa, että keskuspankki pystyy kontrolloimaan inflaatiota (ja -odotuksia) valitsemalla politiikkasäännön, ja seuraamalla sitä uskottavasti. Keskus- ja liikepankkien tasetarkastelun sekä luotonlaajennuksen tarkastelun myötä huomattiin talletusten ja reservien keskeinen rooli rahajärjestelmässä.

Kriisin jälkeisessä tarkastelujaksossa todettiin, että vaikka nimellisen koron alaraja (nolla) on sitova, aiheuttaen edelleen tavanomaisten avomarkkinaoperaatioiden olevan tehottomia, keskuspankki voi stimuloida taloutta määrällisellä elvytyksellä. Näillä epätavanomaisilla avomarkkinaoperaatiolla keskuspankki laajentaa luotonantoa, tarjoaa likvidimpiä varallisuusesineitä yksityiselle sektorille reservien ja julkisen velan muodossa sekä pystyy vaihtamaan politiikkasääntöön, joihin liittyy korkeammat inflaatio-odotukset. Swap-markkinadatan todettiin tukevan väitettä siitä, että pitkän maturiteetin varallisuusesineiden ostot, ja sitä möytä kasvaneet keskuspankkitaseet, onnistuivat nostamaan inflaatio-odotuksia Yhdysvalloissa ja Iso-Britanniassa kriisin keskellä. Tutkielma esittelee myös epätoivotun rahapoliittisen tilanteen, likviditeettiloukun, jossa nimellinen korko saavuttaa alarajansa (nolla) eikä sitä voi laskea alemmaksi. Potentiaalisia vaihtoehtoja päästä pois likviditeettiloukusta esitetään.

Avainsanat

rahapolitiikka
inflaatio
inflatatio-odotukset
tavanomainen rahapolitiikka
epätavanomainen rahapolitiikka
määrällinen elvytys
avomarkkinaoperaatiot
finanssikriisi
likviditeettiloukku

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Denna avhandling närmar sig penningpolitiken genom att dela tiden i två observationsperioder i förhollande till den senaste globala finanskrisen. Dessa perspektiv harstöd av tre olika teoretiska och kvantitativa modeller som tillämpas för att undersöka en centralbanks möjligheter att styra eller påverka inflationen. Den första observationsperioden omfattar tiden från det andra världskriget till slutet av perioden som kallas “Great Moderation", som föregicks krisen. Den andra observationsperioden omfattar tiden från utbrottet av krisen under 2008 till den aktuella dagen.

Denna avhandling är motiverad av några frågor. Först, syftar avhandlingen till att undersöka de grundläggande skillnaderna i penningpolitiken mellan de två observationsperioderna, dvs att undersöka skillnaderna mellan konventionella och okonventionella penningpolitiker. För det andra, försöker avhandlingen att undersöka vilka möjligheter som finns tillgängliga för en centralbank att kontrollera inflationen i olika system och inom båda observationsperioderna. För det tredje, eftersom inflationen är ständigt låg i euroområdet strävar denna avhandling att förklara och ge förslag för att skapa högre inflationsförväntningar och potentiella möjligheter att undkomma en likviditetsfälla.

I den första observationsperioden konstaterades att koordinationen av penning- och finanspolitiken har en nyckelroll med hänsyn till en centralbanks möjligheter att styra eller påverka inflationen. Man fann också, inom en annan modell, att en centralbank kan kontrollera inflationen (och förväntningar) genom att välja och trovärdigt följa en handlingsregel. Vid undersökningen av en central banks och kommersiella bankers balansräkningar och kredit skapande, observerades att insättningar och reserver har en avgörande roll i det monetära systemet.

I den andra observationsperioden, efter krisen, uptäcktes att även om den nedre gränsen (noll) på den nominella räntan är bindande och ytterligare orsakar konventionella öppna marknadsoperationer för att vara ineffektiva, kan centralbanken stimulera ekonomin via kvantitativa lättnader. Via dessa okonventionella öppna marknadsoperationer ger centralbanken mer likvida tillgångar för den privata sektorn i form av reserver och statsskuld, och kan visa engagemang för förändring till en annan handlingsregel som är associerad med högre inflationsförväntningar. Bevis från swap-marknad-data hittades för att stödja påståendet att långsiktiga tillgångs inköp, och därigenom expanderade central bankernas balansräkningar, lyckats öka inflationsförväntningarna i USA och i Storbritannien mitt i krisen. Denna avhandling presenterar också en ovälkommen likviditetsfälla i penningpolitiken, där den nominella räntan träffar den nedre gränsen (noll) och kan inte sänkas vidare. Potentiella lösningar för att undkomma fällan diskuteras.

Nyckelord

penningpolitik
inflation
inflation förväntningar
konventionell penningpolitik
okonventionell penningpolitik
kvantiativ lättnad
öppna marknadsoperationer
finanskris
likviditetsfälla

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1 Introduction

This thesis rethinks monetary policy dividing time into two review-contexts in relation to the recent global financial crisis. The rethinking leans on three different theoretical and quantitative models which are applied in order to examine a central bank's possibilities to control or affect inflation. The first review-context covers the time period from post-WWII to the end of the period of Great Moderation, which preceded the crisis. The second review-context covers the time from the eruption of the crisis in 2008 to the present day.

In normal or pre-crisis times a central bank typically adjusts the short-term interest rate, often referred to as the policy rate, via open market operations. These open market operations involve purchases and sales of short-term treasury bills (e.g. 3-months) and these kinds of monetary policy measures are referred to as conventional monetary policy measures [Farmer 2012]. By adjusting the policy rate, the central bank endeavors to anchor the public's expectations on future inflation, and the anchoring of expectations is a key mechanism in order to reach stable prices in the economy [Sheard 2013b].

The onset of the crisis changed monetary policy dramatically. *"Monetary policy will never be the same after the crisis"* stated Olivier Blanchard (2013) in a major research conference organized by the International Monetary Fund in November 2013. The crisis caused two fundamental changes. First of all, as the key policy rates of western central banks were rapidly brought to zero (or close to) conventional monetary policy measures were not providing sufficient stimulus anymore. This led to unconventional monetary policy measures which consisted of purchases of longer-term government bonds, mortgage-backed securities and other asset-backed securities [Farmer 2012]. These changes in the size and the composition of a central bank's balance sheet are called quantitative easing (QE) measures which aim to ease liquidity, credit conditions or both [Blinder 2010]. By using its balance sheet as a monetary policy instrument the central bank attempts to change the composition of the aggregate portfolio held by the private sector; the central bank rebalances the private sector's aggregate portfolio by purchasing government debt and other securities and in exchange it provides reserves and bank deposits [Sheard 2013a]. Secondly, as a consequence of unconventional monetary policy measures, the size of the balance sheets of central banks such as the Federal Reserve in the US (Fed hereafter) and the Bank of England (BoE hereafter) in the UK increased substantially; as a matter of fact they over doubled within a period of roughly a year [Gertler & Karadi 2011; Farmer 2012; Hofmann & Zhu 2013]. The Lehman-collapse in September 2008 [Farmer 2012] functioned as a catalyst to the eruption of the crisis as most of the increase in the size of the balance sheets followed the Lehman-collapse [Gertler & Karadi 2011].

In addition to monetary policy measure changes, the crisis has been followed by a prolonged period of depression and low inflation, particularly in Europe and in the eurozone. According to the statistics of the European Central Bank (ECB hereafter), the annual inflation rate was as low as 0.3% in November 2014 and it has been under 1.0% since October 2013 [ECB 2014b]. The ECB is constantly failing to reach its inflation target over the medium term, which is below, but close to, 2% over the medium term [ECB 2014c]. This development has raised concerns in public debate that the eurozone is threatened by deflation, a liquidity trap and a lost decade in terms of economic growth. As the central policy rate, the MRO-rate of the ECB is set to 0.05%, the zero lower bound of the nominal interest rate is already binding in practice. Given the persistently low inflation rate, the ECB is eagerly attempting to find measures (other than conventional monetary policy measures) to provide sufficient stimulus to the eurozone economy and increase inflation expectations among the public. As an example, the ECB has recently complemented its regular open market operations by two liquidity-providing, long-term refinancing operations (LTRO) and by a series of targeted longer-term refinancing operations (TLTRO) and a couple of asset or covered-bond purchase programs. There are differences among the programs relating to how much they have been already used [ECB 2014a]. As the ECB is slowly moving towards implementing a quantitative easing policy, the Fed's QE-measures, that were *"the biggest emergency economics stimulus in history"* adding over $3.5 trillion to the Fed's balance sheet (that is equal to the size of the German economy), has come to the end after gradually tapering the measures since 2013 [Bloomberg 2014]. The eurozone is thereby in a different stage of recovery from the crisis.

The enormous changes of monetary policy mainly dealt with in this thesis, are compelling and fascinating. As the quote of Blanchard (2013) indicates considering the current post-crisis period, when monetary policy returns to "normal times" it will be vastly different. What that *different* shall be, is for the moment unknown. But this far it seems that unconventional monetary policy has become "the new normal."

This thesis is motivated by a several questions. First of all, the thesis aims to examine the fundamental differences in monetary policy between the pre and the post-crisis periods, i.e. to examine the differences between conventional and unconventional monetary policies. Secondly, the thesis attempts to examine what possibilities are available to a central bank in controlling inflation in different schemes and within both contexts. Thirdly, as the inflation rate is persistently low in the eurozone this thesis endeavors to explain and provide suggestions to create higher inflation expectations and potential options to escape a liquidity trap situation. Finally, the fundamental goal of this thesis is to better understand the current monetary system and broadly rethink monetary policy from different viewpoints as it is obvious that monetary policy is still evolving in the aftermath of the crisis.

The structure of this thesis is as follows: Chapter 2 examines monetary policy in the traditional pre-crisis context. It introduces two different kinds of theoretical frameworks. The first is a theoretical framework constructed by Sargent & Wallace (1981), which examines the possibilities of a central bank to control inflation depending on how monetary and fiscal policies are coordinated. The latter theoretical framework is by Farmer (2012) and is a one-period rational expectations RBC-model, which provides a framework to analyze how certain monetary policy rules will affect inflation and interest rates. Moreover, it manages to explain relatively well the history of inflation in the US in both pre and post-crisis periods. It is a very useful model as it can be applied in both contexts, it explains particularly well why conventional monetary policy measures become impotent, and it describes how unconventional policy measures are supposed to help. Chapter 3 examines monetary policy in the post-crisis context, where unconventional monetary policy measures will in fact become as new conventional. This chapter also presents credit creation and the balance sheets of the banking system entities, as understanding these fundamentals of them is essential in order to understand how unconventional monetary policy measures are supposed to affect inflation and how they change the balance sheets of the entities. Besides, the model of Farmer (2012), chapter 3 introduces a model of unconventional monetary policy by Gertler and Karadi (2011), which is a state-of-the-art DSGE-model. Chapter 4 introduces an unwelcome problem of monetary policy, namely a liquidity trap, which is currently a real threat particularly in Europe, and of which Japan has experience since the 1990s [Svensson 2003]. It also provides options and solutions on how to exit the trap, mainly dealing with the ideas of Svensson (2003). The last chapter 5 draws conclusions.

2 Traditional monetary policy: the pre-crisis context

2.1 Foreword

The role of monetary policy - what it can do, and it cannot do has always been debatable. In his famous article "The Role of Monetary Policy" Friedman (1968) talks about monetary policy, particularly what it can contribute, how it is conducted and what one should expect from it. He describes how the Great Contraction destroyed the popular belief of the 1920s that monetary policy technology had managed to make business cycles somehow obsoleted. Friedman (1968) continues describing the opinions on monetary policy after the Great Contraction: "*Monetary policy was a string. You could pull on it to stop inflation but you could not push on it to halt recession. You could lead a horse to water but you could not make him drink*". In generally, Friedman (1968) warns not to expect too much from monetary policy.

Friedman (1968) states that a monetary authority is able to control nominal quantities as they are its own liabilities. It follows that the monetary authority can peg any nominal quantity such as the exchange rate, price level, nominal level of national income or quantity of money by some definition. Moreover, the monetary authority can peg the rate of change in nominal quantity, such as the rate of inflation or the rate of growth of the quantity of money. It is worth noting that only nominal quantity can be pegged. The monetary authority cannot peg a real quantity, such as the real rate of interest or the real quantity of money. However, monetary policy can influence and have a disturbances-offsetting impact on these real magnitudes and is thus useful [Friedman 1968].

About the conduction of monetary policy Friedman (1968) writes that the monetary authority should *guide* itself by some magnitudes that are in its control, not by ones that are out of its control. Friedman (1968) suggests the most appealing guides for the monetary authority's policy can be the price level as defined by some index, the exchange rates or the quantity of a monetary total. From these three listed guide options he prefers the price level to be the most important. Despite this Friedman (1968) argues that the price level guide is problematic as its link to policy action is more indirect compered with when the action is guided by a monetary aggregate. The lag of a monetary action is longer with the price level target and its effect cannot be predicted accurately, which may contribute to monetary policy being a source of economic disturbance due to false stops and starts. Therefore, at that time, Friedman preferred a monetary total to be the best available guide for monetary policy, and according to his suggestion, a monetary total consisting of currency in circulation plus commercial bank deposits, should grow 3-5 % on a yearly basis. [Friedman 1968].

Moreover, Friedman (1968) advocates that sharp swings in monetary policy conducting should be avoided. He gives an example from the Great Contraction where monetary policy was moved in the wrong direction. Further, he points out that even if monetary policy was moved in the right direction it might still be too late and possibly too far. As an example Friedman (1968) demonstrates the events in 1966 in the USA when the Fed moved correctly in a less expansionary direction but too late. By moving too late, it produced the sharpest change in the rate of monetary growth since WWII and by trying to restore the situation at the end of 1966, the Fed went again too far exceeding the earlier excessive rate of monetary growth. [Friedman 1968].

The reason for easily overreacting is of course the lag between an action and its subsequent effect. It is hard to estimate if it will be six, nine, twelve or even fifteen months when the action affects the economy and hence, in the case of a difficult situation, the monetary authority feels forced to react rather strongly. As a remedy for this, Friedman (1968) suggests the monetary authority adopt a publicly-known fixed growth-rate in some monetary aggregate. By setting *a rule* and keeping it, the monetary authority can contribute in a major way to promoting economic stability. [Friedman 1968].

2.2 Inflation targeting

Before the onset of the crisis, monetary policy was broadly and undoubtedly thought to be the best tool for governments to use in order to achieve good macroeconomic performance in terms of a high employment rate and stable prices. Moreover, concentration on the price stability was considered the best way to achieve full employment and to smooth business fluctuations. A stable and low inflation rate was desirable, and inflation targeting was a trusted practice of central banks. [Sheard 2013b].

Inflation targeting means that a central bank has an explicit inflation target as the main principle to guide the conducting of monetary policy. An explicit inflation target has been increasingly popular since the early 1990s and in fact has brought less volatility to the level and variability of inflation [Woodford 2004]. Before the year 1990, it was typical for central banks to target monetary aggregates instead of inflation targets [Benes and Kumhof 2012]. Inflation-forecast targeting (or more precisely *defining*) is a systematic decision-making procedure behind monetary policy conducting which has its roots in various central banks like such the Bank of England, the Bank of Sweden, the Reserve Bank of New Zealand, and the Bank of Canada. The main principle of monetary policy guidance has thus been born *within* the central banks rather than from academic literature or on the basis of theoretical monetary economics. [Woodford 2004].

What makes an explicit inflation target well-functioning is its public announcement and the fact that it is a quantitative target by nature. A central bank is expected to show *commitment* to this explicitly set target in terms of policy deliberations and communications with the public. As a matter of fact, it is more important for the central bank to have any explicitly defined target than to have a particular inflation target. Having an explicit policy target guarantees that the public can have the best possible understanding of the central bank's actions and it also provides democratic legitimacy to monetary policy. Inflation targeting has been a pioneering approach in monetary policy conducting, where transparency and the role of quantitative projections of the economy's future in policy decisions play central roles. [Woodford 2004].

A central bank conducts monetary policy independently from the government and legislatures, but within the mandate it has received from them [Sheard 2013b]. The mandate is generally price stability, but there are differences in the specifications. For example, the European Central Bank's mandate is defined in the Treaty on the Functioning of the European Union, Article 127(1) as:

> "*The primary objective of the European System of Central Banks (hereinafter referred to as "the ESCB") shall be to maintain price stability. Without prejudice to the objective of price stability, the ESCB shall support the general economic policies in the Union with a view to contributing to the achievement of the objectives of the Union as laid down in Article 3 of the Treaty on European Union.*"

Note, that the ECB's mandate includes primarily just one objective (price stability), whereas the Fed has actually three parallel monetary policy objectives (marked in bold) as:

> "*The Board of Governors of the Federal Reserve System and the Federal Open Market Committee shall maintain long run growth of the monetary and credit aggregates commensurate with the economy's long run potential to increase production, so as to promote effectively the goals of* ***maximum employment****,* ***stable prices****, and* ***moderate long-term interest rates*** [Federal Reserve Act, Section 2A]."

To target inflation, a central bank uses its government-legalized tools independently, which normally means adjusting its policy rate upwards or downwards, depending on whether it is desired that financial conditions be tightened or loosened. The adjustment of the policy rate happens via open market operations, where the central bank either sells or purchases government bills or bonds and thereby adjusts the amount of bank reserves which are liabilities on its balance sheet. By adjusting the policy rate the central bank tries to anchor the public's expectations of future inflation. Being independent from the government, having the legalized tools to alter economic conditions, and by publicly signaling the inflation rate, the central bank endeavors to anchor the public's expectations of future inflation around its inflation target. This becomes a self-fulfilling circle, where anchoring of inflation expectations is a key mechanism in order to reach stable prices. [Sheard 2013b].

Continuing more specifically, let it be defined precisely that the policy rate is typically an overnight interest rate in an interbank market for the central bank balances (for instance the federal funds rate of the Fed). This kind of policy rate has very minimal impact on economic decision-making, after all it is only an interest rate for overnight borrowing. The factor is the kind of impact at change in overnight interest rate has on other financial market prices, such as longer-term interest rates, equity prices and exchange rates. These longer-term financial market prices not only depend on current short-term interest rates but also on all future short-term interest rates. Therefore a central bank's ability to influence the price level depends on its ability to influence market expectations on the future path of overnight interest rates [Woodford 2004]. Being able to influence future inflation expectations is an utterly important issue for a central bank, and this theme will be further examined later in this thesis, particularly as relates to the zero nominal policy rate.

In the inflation targeting framework there is naturally a clear distinction between monetary and fiscal policy, i.e. they are totally independent, which further implies that monetary finance by a central bank is not allowed. Also, market fundamentalism is an essential element that the central bank should not be concerned (too much) about asset prices or any other possible imbalances in the economy or financial system. Rather, asset prices and other imbalances should be dealt with as they occur. Additionally, focusing on inflation targeting means focusing on domestic monetary stability which in turn means that the foreign exchange rate is allowed to float freely. All these presented inflation targeting issues were rather well adopted by central banks before the global financial crisis erupted. [Sheard 2013b].

2.3 Unpleasant monetarist arithmetic

In this subsection traditional monetary policy is studied using the theoretical framework constructed by Sargent and Wallace (1981) which attempts to examine whether a central bank can control inflation. The framework consists of two models, where one is just a specification of the other. The particular framework is a natural choice to be examined as the key things of the two previous subsections are valid in both models. Monetary and fiscal policies are independent of each other, and monetary policy is guided by an explicit target which is a publicly announced base money growth rate. The framework demonstrates that even if an economy is monetarist by nature and if monetary policy is interpreted as open market operations, under certain circumstances, inflation may have to be added to Friedman's (1968) list of variables that monetary authorities cannot permanently control [Sargent and Wallace 1981].

The economy of the models is monetarist with the following two characteristics: (1) "*the monetary base is closely connected to the price level* " and (2) "*the monetary authority can raise seignorage, which means revenue from money creation* [Sargent and Wallace 1981]."

A discussion of seignorage is beneficial as it has a crucial role in this framework. Buiter (2007) describes seignorage[1] thoroughly:

> "*Seigniorage refers historically, in a world with commodity money, to the difference between the face value of a coin and its costs of production and mintage. In fiat money economies, the difference between the face value of a currency note and its marginal printing cost are almost equal to the face value of the note – marginal printing costs are effectively zero. Printing fiat money is therefore a highly profitable activity – one that has been jealously regulated and often monopolized by the state* [Buiter 2007]."

Another example of the definition of seignorage is by The Bank of Canada as follows:

> "*In Canada today, seigniorage can be calculated as the difference between the interest the Bank of Canada earns on a portfolio of Government of Canada securities—in which it invests the total value of all bank notes in circulation—and the cost of issuing, distributing, and replacing those notes* [BOC 2013]."

Christopher Sims (2013) in turn writes seignorage to be an implicit tax which a central bank can use. An instance where this would apply is in the case of having a negative net worth and simultaneously a fiscal backing from treasury is uncertain. Seignorage is fiscal backing a central bank can provide on its own. Seignorage revenues depend positively on the inflation rate when inflation is moderate. Sims (2013) continues that modestly negative net worth can normally be worked off by seignorage without any help from the treasury but in more severe cases a central bank may not be able to hold to its inflation target or other policy objectives. In general, Sims (2013) considers a central bank's balance sheet is of importance as it connects monetary and fiscal policy.

According to Sargent and Wallace (1981) the government of the economy is constrained by the public's demand for the interest-bearing government debt, namely government bonds. The public's demand for these bonds constrains the government at least in two ways: (1) the demand sets an upper limit on the real stock of government bonds relative to the size of the economy and (2) the demand affects

[1] Note that Buiter (2007) uses different spelling

the interest rate the government must pay on its bonds. These two constraints bind the monetarist economy of the models to a different extent depending on how monetary and fiscal policy are coordinated in the economy [Sargent and Wallace 1981].

There are two possibilities in coordination: either monetary policy dominates fiscal policy or vice versa. Let it be first assumed that it is monetary policy that dominates fiscal policy. Under this coordination scheme the monetary authority independently sets its monetary policy by announcing growth rates of base money for the current and all future periods. By doing this it simultaneously determines the level of revenue that will be supplied to the fiscal authority through seignorage. Now, the fiscal authority sets its fiscal policy in turn. It knows the amount of seignorage that the monetary authority chose in the first place, but the public's demand for the government bond constrains its fiscal policy as well. The fiscal authority must set its budgets so that it will be able to finance all current and future deficits by any combination of seignorage and government bond sales. This coordination scheme hence sets constraints to the fiscal authority but the monetary authority is unconstrained to choose any growth rate (and seignorage) for base money. It follows that the monetary authority can permanently control inflation. [Sargent and Wallace 1981].

The other coordination scheme functions as follows. By moving first, the fiscal authority sets all current and future budgets. This movement simultaneously and completely determines the amount of revenue that must be raised through bond sales and seignorage. Now the monetary authority becomes constrained: the demand of the government bonds has an explicit impact on the level of seignorage the monetary authority must raise in order to finance all the needs of the fiscal policy that cannot be covered by the bond sales. In this coordination scheme, the monetary policy cannot control inflation permanently. If the bond sales are low and fiscal deficits cannot be financed, then the monetary authority is forced to create a certain amount of money by seignorage, and thus it must accept additional inflation. [Sargent and Wallace 1981].

A simple example illustrates the relevance of the public's bond demand in this coordination scheme. Let it be assumed that the demand for the government bonds is set so that it yields 5 % interest rate on bonds. Let it be also assumed that the economy grows at the rate of 2 %. Now, if the fiscal authority runs constant deficits the monetary authority must finance those deficits through seignorage, but if the monetary authority chooses to not seignorage, then the fiscal authority will sell more bonds and that will further increase the interest rate on the bonds. It follows that the real stock of bonds grows faster than the economy. This kind of development cannot continue forever. Remembering that the first given constraint of the public's demand on bonds states that the public's demand sets an upper limit on the real stock of government bonds relative to the size of the economy. Once the upper limit is reached, the principal and interest rate must be financed by seignorage, and sooner or later, this will cause additional inflation in this monetarist economy. [Sargent and Wallace 1981].

2.3.1 The models

The two models of Sargent and Wallace (1981) are constructed and replicated now. The first model is extremely monetarist in the following ways: (1) there exists a simple quantity theory demand for base money, (2) the government is allowed to raise seignorage and monetary policy will go as far as necessary influencing the price level, and (3) monetary policy does not have influence on almost any real variables [Sargent and Wallace 1981]. In this model it is examined, what are the implications of exercising tight monetary policy now against current inflation. The model has the following three basic assumptions[2]:

1. "*A common constant growth rate* of n *for real income and population.*
2. *A constant real return on government securities that exceeds* n.
3. *A quantity theory demand schedule for base or high-powered money, one that exhibits constant income velocity* [Sargent and Wallace 1981]."

Note that as the constant real return on government securities exceeds the growth rate of real income and population, these assumptions generate a similar situation that was already examined in the simple numerical example in the previous page. Thus, both models are built so that fiscal policy is dominating.

Let the construction of the model begin by describing fiscal policy in time sequences as $D(1), D(2), ..., D(t)$, where $D(t)$ is in real terms and is defined as all real expenditures excluding interest rate on government debt, minus real tax collections. So, $D(t)$ is the fiscal deficit in real terms (less real interest payments) but will be referred to as the deficit from now on to follow precisely the convention of Sargent and Wallace (1981). Also, time $t = 1$ is referred to the current date. Analogously monetary policy is described in time sequences as $H(1), H(2), ..., H(t)$, where $H(t)$ is the stock of base or high-powered money at time t. For simplicity it is assumed that the entire government debt consists only of one-period debt.

[2]See the Appendix A in Sargent and Wallace (1981), where a GE-model that generates all the three basic assumptions of the examined models is presented.

Thus, the consolidated government budget constraint, which covers the *whole* public sector and all of its instances from the central bank to the treasury, can be written as:

$$D(t) = \frac{H(t) - H(t-1)}{p(t)} + B(t) - B(t-1)(1 + R(t-1)) \tag{1}$$

for $t = 1, 2, ...$. In this equation $p(t)$ is the price level at time t; $B(t)$ is government borrowing from the private sector between periods t and $t+1$, measured in units of time t goods; $R(t-1)$ is the real rate of interest on government bonds between time $t-1$ and time t; $B(t-1)(1+R(t-1))$ is the real par value of one-period privately held government bonds, that were issued at time $t-1$ and fall due in period t, where $B(t-1)$ is measured in units of time $t-1$ goods and $(1+R(t-1))$ is measured in time $\frac{t}{t-1}$ goods. The equation (1) simply says that the deficit must be financed by a combination of seignorage, (the first part of the right-hand side of the equation), and by borrowing with an interest rate (the latter part of the equation). [Sargent and Wallace 1981].

The first basic assumption of the model states a constant growth rate n for real income and population. Let the population at time t be described as $N(t)$. It follows that the evolution of real income and population can be written as:

$$N(t+1) = (1+n)N(t) \tag{2}$$

for $t = 0, 1, 2, ...$ with $N(0) > 0$ and $n > -1$ being as given. Next the consolidated government budget constraint per capita is obtained by dividing the equation (1) by $N(t)$ and after a straightforward rearrangement of the terms it follows that:

$$\frac{B(t)}{N(t)} = \frac{1 + R(t-1)}{1+n} \frac{B(t-1)}{N(t-1)} + \frac{D(t)}{N(t)} - \frac{H(t) - H(t-1)}{N(t)p(t)}. \tag{3}$$

Next, as the consolidated government budget constraint per capita is attained, the effects of exercising tight monetary policy on the current date and its implications on future inflation are studied. To study the implications, the fiscal policy is now taken as given in the form of $D(t)$, and the monetary policy path is now specified so that $H(1)$ is predetermined but for $t = 2, 3, ..., T$, where T is a date ≥ 2, alternative monetary policies are alternative constant growth rates θ of $H(t)$. Also, it is assumed that the attained stock of interest-bearing government debt per capita at time $t = T$ will be held constant in the path of $H(t)$ for $t > T$. This assumption is feasible as the first constraint of the public's demand on bonds set an upper limit to the amount of debt (per capita). Thus, formulating the alternative monetary policies with $H(1)$ as given it is obtained:

$$H(t) = (1 + \theta)H(t - 1) \tag{4}$$

for $t = 2, 3, ..., T$. Note that θ describes monetary policy tuning. The smaller is the value of θ, the tighter is the monetary policy tuning. It follows that the greater is the value of θ, the greater is the stock of base money or high-powered money $H(t)$ at time t. The interpretation of θ is in other words that it describes the open market operations. [Sargent and Wallace 1981].

It must be ensured that, within the model, anticipated inflation equals to actual inflation as the equation (1) is in real terms and the government bonds are not indexed. The equivalence of inflations is guaranteed with the assumption of simultaneous public announcement of both, the path of fiscal policy $D(t)$, and the path of monetary policy in the form of θ and T at time $t = 1$. Assuming this, the form of new issued debt from $t = 1$ does not have any specific role. [Sargent and Wallace 1981].

Next the price level at time t is formulated. The basic assumptions (1.) and (3.) straightforwardly imply that the price level $p(t)$ is proportional to the stock of base money per capita $\frac{H(t)}{N(t)}$ at time t. Thus, the quantity equation of money is given as:

$$p(t) = \frac{H(t)}{N(t)} \frac{1}{h} \tag{5}$$

for some positive constant h. From the quantity equation of money, and by using the equation (2) the inflation rate is obtained as:

$$\frac{p(t)}{p(t-1)} = \frac{(1 + \theta)}{(1 + n)}$$

for $t = 2, ..., T$. Hence, it is noted that prices increase in tandem with money supply which sounds reasonable. Also, as the monetary policy is specified at time $t = 1$ by announcing θ and T, the inflation rate for periods $t = 2, ..., T$ is simultaneously determined. Next, the fundamental question is how the inflation rate in periods $t > T$ depends on the inflation rate that was chosen (by the announcement) for the periods $t \leq T$. The answer will be attained by two simple steps, where in the first step it is determined how the inflation rate in periods $t > T$ depends on the stock of interest-bearing real government debt per capita attained at time T, being held constant thereafter, and denoted as $b_\theta(T)$. In the second step it is showed how $b_\theta(T)$ depends on θ. [Sargent and Wallace 1981].

The government consolidated budget constraint equation (3) must be used again but now $\frac{B(t)}{N(t)} = \frac{B(t-1)}{N(t-1)}$ is substituted by $b_\theta(T)$ and $H(t)$ is substituted by $hN(t)p(t)$ that follows from the equation (5). Now it is obtained:

$$1 - \frac{1}{(1+n)}\frac{p(t-1)}{p(t)} = \frac{\frac{D(t)}{N(t)} + \frac{R(t-1)-n}{(1+n)}b_\theta(T)}{h}. \tag{6}$$

Noting, that by the second basic assumption of the model, the term $R(t-1)-n$, is always positive and constant. Thus, the right hand side of the equation is positive. The right-hand side of the equation (6) is greater, the greater $b_\theta(T)$ is. This in turn implies that for all $t > T$, the inflation rate is higher, the higher $b_\theta(T)$ is. [Sargent and Wallace 1981].

Now as it is proved that the inflation rate in time periods after T is greater the greater is the stock of interest-bearing real government debt per capita attained at time T, the second step, i. e. how this attained debt $b_\theta(T)$ depends on θ, must be yet examined. The government consolidated budget constraint is used again with some substitutions. Firstly, a following definition is used $\frac{B(1)}{N(1)} \equiv b(1)$ and then the entire path $b(1), b_\theta(2), b_\theta(3), ..., b_\theta(T)$ is found. [Sargent and Wallace 1981].

Solving $b(1)$ from the equation (3) with $t = 1$, and replacing $B(0)(1+R(0))$ with $\frac{\bar{B}(0)}{p(1)}$ in order to avoid assuming anything about the relationship between actual and expected inflation between periods $t = 0$ and $t = 1$ and as $\bar{B}(0)$ is the nominal par value of the debt issued at time $t = 0$, it is finally obtained:

$$b(1) = \frac{\bar{B}(0)}{N(1)p(1)} + \frac{D(1)}{N(1)} - \frac{H(1) - H(0)}{N(1)p(1)}. \tag{7}$$

It can be seen that $b(1)$ does not depend on θ. Now the definition $b(t) \equiv \frac{B(t)}{N(t)}$ is applied and the equations (4) and (5) are used to obtain the entire path $b(1), b_\theta(2), b_\theta(3), ..., b_\theta(T)$. With these instructions the equation (3) can be written as:

$$b(t) = \frac{1 + R(t-1)}{1+n}b(t-1) + \frac{D(t)}{N(t)} - \frac{h\theta}{(1+\theta)} \tag{8}$$

for $t = 2, 3, ..., T$ and by repeated substitution for any $t > 2$ and $t \leq T$ it is followed that

$$b_\theta(t) = \phi(t,1)b(1) + \sum_{s=2}^{t} \phi(t,s)\frac{D(s)}{N(s)} - \frac{h\theta}{(1+\theta)}\sum_{s=2}^{t}\phi(t,s) \tag{9}$$

where $\phi(t,t) = 1$ and for $t > s$, $\phi(t,s) = \frac{\prod_{j=s}^{t-1}(1+R(j))}{(1+n)^{t-s}}$. [Sargent and Wallace 1981].

From equation (9) it follows that $b_\theta(T)$ is greater, the smaller θ is. In other words, the tighter monetary policy is, the greater the attained real government debt per capita is, at time $t = T$. Thus, within this model, it can be concluded that by fighting current inflation by exercising tighter monetary policy now, the government merely shifts inflation to future periods. The monetary authority is able to control inflation only temporarily but eventually higher inflation will occur. [Sargent and Wallace 1981]

It should not be forgotten that in the above-constructed model anticipated inflation is supposed to equal actual inflation, and also that the model does not take into account a relationship between demand for base money and the expected rate of inflation; equation (5) is merely a simple money demand schedule. There is a plenty of empirical evidence supporting the existence of this dependence between demand for base money and the expected rate of inflation, for instance Bresciani-Turroni (1937) and Cagan (1956) have studied this. Thus, the previous model is modified a bit to make it more realistic. [Sargent and Wallace 1981].

To construct a more realistic model, by still following Sargent and Wallace (1981), only one small specification for the previous model must be done in order to take into account the expressed shortcomings of the first model. All others remain unchanged, but the quantity equation of money i.e. equation (5) is now replaced by:

$$\frac{H(t)}{N(t)p(t)} = \frac{\gamma_1}{2} + \frac{\gamma_2}{2}\frac{p(t+1)}{p(t)} \tag{10}$$

for $t \geq 1$ with $\gamma_1 > \gamma_2 > 0$. This money demand schedule is the same as Cagan (1956) used in studying hyperinflations, and the equation further implies a new equation for the price level at time t to be:

$$p(t) = \frac{2}{\gamma_1}\sum_{j=0}^{\infty}(\frac{\gamma_2}{\gamma_1})^j\frac{H(t+j)}{N(t+j)}.$$

Now as the expectations are taken into account, the impact of exercised monetary policy on the price level must be revised. The dependence between the demand of base money and expected future inflation implies that the current price level does not only depend on the current level of money supply but also on all anticipated future money supply levels. This in turn indicates that the higher the anticipated money supply in the future is, the higher the current rate of inflation is. As a consequence of this, reaching even temporary, immediate help for current high inflation by exercising tighter monetary policy may not be possible within this modified model. [Sargent and Wallace 1981].

As already stated, the fundamentals of this modified model are the same as in the first one: a fiscal policy deficit sequence $D(t)$, a date T after which the real interest-bearing government debt per capita is being held constant and the growth rate of the monetary base for periods before T, θ, are all included and now all of these have an impact on the path of the price level before T [Sargent and Wallace 1981].

To study the implications of tighter monetary policy on inflation within this modified model, let a numerical example that Sargent and Wallace (1981) provide be examined. In this example, the economy is characterized such that $\gamma_1 = 3.0$, $\gamma_2 = 2.5$, $R = 0.05$ and $n = 0.02$. Fiscal and monetary policies are now as follows: a per capita deficit sequence $d(t)$ is $d(t) = 0.05$, for $t = 1, 2, ..., 10$ and $d(t) = 0$ for $t > 10$; $T = 10$. Moreover, $\frac{H(0)+\bar{B}(0)}{H(1)} = \frac{200}{164.65}$ and both base money growth rates $\theta = 0.106$ and $\theta = 0.120$ are examined. This results in a rather paradoxical situation: the price level at time $t = 1$ is 1.04 % higher under the smaller (tighter) θ .Thus, according to this model an optimal way to fight current inflation is by exercising looser monetary policy rather than tighter - this is unpleasant monetarist arithmetic. As a matter of fact, moving from tighter monetary policy to looser monetary policy, would be a Pareto-improvement. In the first presented model tighter monetary policy could at least temporarily reduce inflation but in this modified model tight monetary policy is totally impotent to reduce inflation [Sargent and Wallace 1981].

2.3.2 Model conclusions

The results and implications of the theoretical framework presented in the previous sub-subsection are interesting and relevant to consider. With only two crucial assumptions, i.e. with the real interest rate exceeding the growth rate of the economy and with the assumption of monetary and fiscal policy independence, it resulted a situation where the monetary authority was basically unable to control or affect inflation. In other words, monetary policy became impotent. The latter crucial assumption is more interesting as it stems from the behavior of the monetary and fiscal authorities and the game that they are playing [Sargent and Wallace 1981].

The coordination issue is very fundamental in this framework; the ability of the monetary authority to control or affect inflation is totally dependent on it. This game that the authorities are playing in these models, is on in which the fiscal authority dominates and monetary policy is only consistently determined on the basis of fiscal policy. Hence, the fiscal authority imposes discipline on the monetary authority. Under this coordination scheme, and given the first crucial assumption, the main result of both models can be summarized by stating that making money tighter now makes only makes it looser later. [Sargent and Wallace 1981]

Note that, the models could have been constructed so that it is the monetary authority that moves first and hence imposes discipline on the fiscal authority. In that case, the monetary authority moves first by announcing permanently a fixed θ rule for all $t \geq 1$. The permanent monetary policy announcement guarantees that the fiscal authority is being dominated and it binds the fiscal authority to choose a $D(t)$ sequence consistent with the monetary policy. Permanent monetary restraint is an effective mechanism that guarantees fiscal discipline like other monetary mechanisms e.g. fixed exchange rates or the gold standard. Importantly, the above-constructed models do not present anything that would suggest that in the coordination scheme where monetary policy dominates, monetary policy could not permanently affect the inflation rate. [Sargent and Wallace 1981].

The classic article of Sargent and Wallace (1981) has become relevant again, as in the aftermath of the crisis monetary authorities are considering ways to boost inflation. However, the post-crisis monetary policies and the monetary system have developed and come a long way from the early 1980s. Thus this framework does not necessarily provide any help in terms of analyzing the situation in the post-crisis period. A central bank's ability to control or affect inflation will be examined in a totally different theoretical framework in chapter 3. However, in this traditional context, the findings of Sargent and Wallace (1981) are profound and thorough and it seems to defend the idea that monetary policy should be the dominating authority.

2.4 An augmented RBC-model including the monetary and financial sectors

In this subsection a model that explains the effect of monetary policy rules on inflation expectations is introduced. The particular model is a one-period RBC model which is augmented with a complete monetary and financial sector. The model is constructed by Farmer (2012) and it can be applied to examining inflation expectations in both conventional and unconventional monetary policy frameworks. By examining calibrated examples of the model it can be illustrated that the particular model actually explains fairly well the history of inflation in both pre and post-crisis periods. Moreover, it provides evidence that the unconventional monetary policy actions that followed after the Lehman-collapse had stabilizing effects on future inflation expectations. [Farmer 2012]. From the viewpoint of this thesis's central questions, the model is very useful as it not only explains how an interest rule can be used to control inflation in normal times, but also explains the purpose of unconventional monetary policy measures when the zero lower bound is reached.

As an RBC model, the model leans on classical economists' developments such as rational expectations, flexible prices and single representative agent form. In addition, the augmentation of the complete financial and monetary sector provides a framework to analyze the connection between money, interest rates and prices. The core monetary model, as Farmer (2012) calls it, has two key ingredients: first of all, agents have rational expectations and secondly, the central bank follows a rule in its policy. The core monetary model does not explain any real economic activity; monetary policy and output are assumed to be independent as the model presumes preferences, endowments and technology to determine output. [Farmer 2012] This assumption may sound irrational but it will be later shown that it does not cause any harm to the analysis of this model.

Before starting to construct the model let the terms *conventional monetary policy* and *unconventional monetary policy* be revised. Conventional monetary policy refers to monetary policy which is conducted through purchases and sales of 3-month treasury bills on the open market and which involves policy rate changes as well. Unconventional monetary policy (in this model) refers to monetary policy, where the central bank is engaged in purchases of variety of assets such as mortgage-backed securities and longer-term government bonds and thus extends credit to the private economy. [Farmer 2012].

2.4.1 Rational expectations and stationarity

As it was already stated, rational expectations are applied in the model. Consequently, agents who are the population of the model, are assumed to use correct and model-consistent probability densities to form expectations on future inflation. The model is also stationary, the most important implication of this is that agents are capable to learn by observation what the previously mentioned probability densities are in practice. Models which have these two features can be represented by stochastic difference equations of the kind:

$$s' = g(s, \epsilon') \tag{11}$$

$$X = \phi(s) \tag{12}$$

where s is a vector of state variables in the current period, X is a set of variables of interest, prime on a variable tells it occurs in the subsequent period and $\epsilon\prime$ is a random event that causes the state to change from s to $s\prime$. The upper difference equation describes the evolution of states that happens by a rule captured by the function $g(\cdot)$. The set of variables of interest, X, depends on the state that is captured by the function $\phi(s)$ upon which the expectations are built. By stationary, it is assumed that the set of variables X may not change over time, which in other words means that every time the economy enters a certain state, the set of variables X obtain the same values. [Farmer 2012].

2.4.2 Asset pricing and financial markets

Contingent trades are typical in modern financial markets and contingent claim is a concept in finance also known as an Arrow security. *"Arrow security is a promise to deliver one dollar in state $s\prime$, if and only if state $s\prime$ occurs* [Farmer 2012]". Now every financial security can be represented as a collection of these Arrow securities. The price of an Arrow security is called the pricing kernel and in this model it is described by a function $Q(s, s\prime)$ [Farmer 2012]. This pricing kernel is a stochastic discount factor (SDF hereafter) [Back 2010] that can be defined in a following way: let initial prices of some assets be $q_1, q_2, ..., q_n$[3] at the beginning of a period, and let the payoffs of these assets at the end of this period be $(q + d)\prime_1, (q + d)\prime_2, ..., (q + d)\prime_n$. Now the SDF is any random variable $Q(s, s\prime)$ that satisfies:

$$E[Q(s, s\prime)(q + d)\prime_i] = q_i, \forall i.$$

This results from the fact that in richer models the second argument of the SDF $Q(s, s\prime)$ is rather a set of values, and such function is called a kernel and this in turn is related to integral transform in mathematics [Farmer 2012].

Returning back to the notation of the model by Farmer (2012), let there be an asset, say a government bond, that costs today $q(s)$ and that pays a stream of coupon payments $\{d(s\prime), d(s\prime\prime), ...\}$ in future corresponding states $\{s\prime, s\prime\prime, ...\}$. This government bond can be priced by the asset pricing equation:

$$q(s) = \sum_{s\prime} \{Q(s, s\prime)[q(s\prime) + d(s\prime)]\} \tag{13}$$

[3] price is denoted with q to be consistent with the slightly unorthodox notation of Farmer (2012)

where the left hand side is the price of the government bond today and the right hand side sums the pay-offs of the government bond tomorrow over all possible following states weighted by the pricing kernel. This same equation can be applied to all securities, and yet on the right hand side the $q(s\prime)$ term refers to the resale value of the security and the $d(s\prime)$ is a dividend term. [Farmer 2012].

2.4.3 Financial markets and the central bank

A central bank intervention occurs through open market operations, i.e. by buying and selling securities. Let a one-dollar treasury bill, that pays $(1+i)$ dollars in the next period, be considered and let it be also reasonably assumed that the government will not default on its bond. The government is thus able to pay the promised $(1+i)$ no matter which state occurs in the next period. Considering the pricing equation (13), the resale price $q(s\prime)$ equals 1 and the coupon payment $d(s\prime)$ equals to i. Now applying these as complete purchases to the pricing equation (13) the interest rate i is related to the prices of Arrow securities as:

$$1 = \sum_{s\prime} Q(s, s\prime)(1+i) \tag{14}$$

and rearranging this it can be seen that the gross interest rate $(1+i)$ is the inverse of the sum of the Arrow security prices:

$$(1+i) = \frac{1}{\sum_{s\prime} Q(s, s\prime)}. \tag{15}$$

The central bank can affect the pricing kernel by buying and selling securities. If the central bank raises (or lowers) its policy rate, the sum of the Arrow securities must go down (up). Before seeing how central bank interventions affect inflation and GDP, the preferences of the agents and the technology for transforming commodities into one another must be specified. [Farmer 2012].

2.4.4 The determinants of the pricing kernel

Let the pricing kernel $Q(s, s\prime)$ be examined yet a bit more thoroughly as it plays a central role in this model. The pricing kernel tells the price which an agent can trade a dollar today, in state s, for a dollar tomorrow in state $s\prime$. The pricing kernel depends on the preferences of households, endowments of labor and land and the available technology. The core monetary model has a few simplified assumptions which further imply that $Q(s, s\prime)$ is a function of (1) the inflation rate, (2) the growth rate of real GDP and (3) the conditional probability of the occurrence of the state $s\prime$. The relationship between Q, inflation and GDP growth is expressed by a function $f[\pi(s\prime), \Delta y(s\prime)]$ where the properties of the function depend on the assumptions of the complete macroeconomic model. By describing with $p_{s,s\prime}$

the conditional probability that the state $s\prime$ will occur next given that state s occurred today, the $Q(s, s\prime)$ can be written as:

$$Q(s, s\prime) = p_{s,s\prime} f[\pi(s\prime), \Delta y(s\prime)]. \tag{16}$$

By assuming common forms of preferences for the representative agent, the function f takes the form:

$$f[\pi(s\prime), \Delta y(s\prime)] = \beta \frac{1}{\pi(s\prime)} \frac{1}{(\Delta y(s\prime))^{\rho}} \tag{17}$$

where $\rho \geq 0$ and the greater the ρ is, the more risk-averse the particular agent is. The β in turn is an impatience term describing the time-preference of the agent. $\beta \in [0, 1]$. [Farmer 2012].

2.4.5 Monetary policy rule

The central bank normally responds to the changes in current inflation or output growth and these responses can be presented by a simplified reaction function

$$(1 + i) = \psi[\pi(s), \Delta y(s)] \tag{18}$$

where the terms in the brackets on the right hand side are for inflation and output growth respectively. Now as the main interest is in inflation, let it be examined what kind of implications the reaction function has for the inflation rate. By using equations (15)-(18), the link between the current inflation rate in the current state and the inflation rate in each future state can be written as a stochastic version of the familiar Fisher equation:

$$\frac{1}{\psi[\pi(s), \Delta y(s)]} = \sum_{s\prime} p_{s,s\prime} [\pi(s\prime), \Delta y(s\prime)]. \tag{19}$$

In order to see that together, both the Fisher equation and the central bank's reaction function determine inflation, a simple example is examined. In this example only one state exists and there is no economic growth, so $\Delta y = 1$. By using equations (15) and (17) it is obtained:

$$\frac{1}{1 + i} = \beta \frac{1}{\pi} \tag{20}$$

where the left hand side of the equation is the inverse of the gross interest rate and the right hand side is a shrunken version of the equation (17) as there is only one state and no uncertainty exists.

Now taking the monetary policy rule from the central bank reaction function and substituting it to the gross interest rate (left hand side) it follows that:

$$\frac{1}{\psi(\pi,1)} = \beta\frac{1}{\pi}. \tag{21}$$

The monetary policy rule on the left hand side determines the money interest rate as a function of current inflation. The denominator $\psi(\pi, 1)$ is an increasing function of π implying that an increase in current inflation leads to a fall in the price of a promise to deliver 1 dollar next period no matter which state occurs. The price of this promise is $q(s)$ and since there is only one state in this example the price of the pure discounted bond is the inverse of the gross interest rate $(1 + i)$. The right hand side of the equation in turn depends on the expected future inflation rate, and it is the stationarity assumption that justifies the use of the same symbol for both concepts. By choosing the policy rule $\psi(\pi, 1)$, the central bank also chooses the steady-state inflation rate and is hence able to totally control inflation. [Farmer 2012].

Returning back to the stochastic version of the Fisher equation, let the stochastic environment be extended now so that there are two states and GDP may fluctuate across them. In this extension there is a different inflation rate and a different growth rate for each state. Thus, the Fisher equation has now two equations with four unknowns:

$$\frac{1}{\psi[\pi(a),\Delta y(a)]} = p_{a,a}f[\pi(a),\Delta y(a)] + p_{a,b}f[\pi(b),\Delta y(b)],$$

$$\frac{1}{\psi[\pi(b),\Delta y(b)]} = p_{b,a}f[\pi(a),\Delta y(a)] + p_{b,b}f[\pi(b),\Delta y(b)]. \tag{22}$$

The economy is initially in either one of the states a (upper equation) or b (lower equation). Again the left hand side in both rows describes the current inflation and GDP growth rate, and the right hand side describes the future inflation and GDP growth rate weighted by the probabilities to end up in each state. Thus the four unknowns are the variables of interest, namely $\pi(a), \Delta y(a), \pi(b)$ and $\Delta y(b)$. To determine them all, two more equations are needed and after that it is possible to determine inflation in each state. [Farmer 2012].

2.4.6 Inflation and growth in the core monetary model

As it was stated earlier, in this model monetary policy has impact on economic activity neither in the short run nor in the long run. Economic activity may fluctuate, but monetary policy does not have any contribution to that. It happens only because the economy fluctuates between the states. It is worth remembering that every time the economy reaches a certain state the variables of interest obtain the same value. The assumption of independence between monetary policy and economic growth allows the economic growth to be determined as follows:

$$\Delta y(s) = \Delta y_a,$$

$$\Delta y(s) = \Delta y_b \tag{23}$$

where subscript a indicates the high growth rate that occurs when the economy enters the state a, and subscript b indicates the lower growth rate that occurs every time the economy enters the state b. These two equations supplement the system and all four unknown variables can now be solved. [Farmer 2012].

Before going to the calibrated examples, the monetary policy rule must be yet determined. The central bank is assumed to follow the subsequent policy rule:

$$\psi[\pi(s), \Delta y(s)] = \bar{I}\pi(s)^{\eta}\Delta y(s)^{\phi} \tag{24}$$

where $\bar{I}$ is the zero-inflation target, i.e. the interest rate that would be chosen if inflation was zero. Parameters η and ϕ are reaction coefficients for inflation and GDP growth. The interpretation of the reaction coefficients is that they change by the same percentages, and to the same direction as the inflation rate or GDP growth rate change. [Farmer 2012].

2.4.7 Calibrated examples explaining the conventional monetary policy

As the model is now entirely constructed, the calibrated examples are studied next. The calibrated parameters $\bar{I}$, η and ϕ are all from the central bank's policy rule equation (24), and it is worth examining how different values of these parameters affect the inflation rate in different states in a rational expectations equilibrium. Table 1 on the following page summarizes the assumptions about the parameters in the difference equations (22). Table 2 compares two different kinds of policy rules which differ only in the value of parameter η, namely the inflation reaction coefficient. The values of inflation

Table 1: Assumptions

Time preference	Risk aversion	Probability of staying in state a	Probability of staying in state b	Growth rate in state a	Growth rate in state b
β	ρ	$p_{a,a}$	$p_{b,b}$	$\Delta y(a)$	$\Delta y(b)$
0.97	2.0	0.9	0.95	4%	1%

Table 2: The effect of changing the inflation reaction coefficient

$\bar{I}$	η	ϕ	$\pi(a)$	$\pi(b)$	$I(a)$	$I(b)$
1.05	1.1	0	37.7%	13.6%	49.2%	20.8%
1.05	2	0	5.1%	0.06%	15.9%	6.4%

and interest rates in table 2 are the solutions to the non-linear equations (22) and (23) [Farmer 2012].

From table 2 it can be seen that looser monetary policy rule, i.e. the first row, leads to very high and volatile inflation and interest rates in both states, whereas the more aggressive monetary policy rule yields relatively stable or at least more preferable states with inflation rate 5.1% for state a and 0.06% for state b, and the interest rates 15.5% and 6.4% respectively. [Farmer 2012].

There are two central reasons why the more aggressive policy rule leads to lower and less volatile inflation: (1) the assumption of rational expectations among households and (2) the central bank's commitment to follow a rule. Let an example be considered where the central bank raises the (short-term) interest rate. By the Fisher equation, it follows that the expected inflation must increase to maintain the no-arbitrage condition. The return on a risk-adjusted nominal bond must be equally attractive as the return on a real asset investment. An increase in inflation expectations can happen via two channels. Either the current price of goods fall, while the expectation of future goods prices remains fixed, or the expected future prices of goods increase, while the current goods prices remain fixed. Both these channels are operative as the model assumes flexible prices in addition to rational expectations. The more aggressive policy rule leads to more stable economy as it allows real rates of return to adjust, when a real shock hits the economy, through a change in nominal interest rate rather than through a change in inflation. [Farmer 2012].

Farmer (2012) points out that the first policy rule in table 2 describes relatively well the period from 1960-1979 when inflation was high and volatile in the United States. The rule in the second row in turn fits well to the period of 1983-2006 that is often called the period of "Great Moderation" when stable inflation, unemployment and GDP growth were typical for the US. These claims are also supported by the empirical analysis of Lubik and Schorfheide (2004).

To conclude the findings of this model in the pre-crisis (normal times) context, it can be said that the central bank is able to control inflation and also expectations in this framework. By choosing a policy rule, the central bank also chooses a steady state inflation rate. By following a more aggressive rule the central bank allows the real rates of return to adjust through a change in nominal interest rate, rather than through a change in inflation. Despite its shortcomings and strong simplifications, such as the independence between monetary policy and real economy, the above-described RBC-model is useful and the ideas of it contains can be brought to more realistic models in which central bank policy affects real economy as well. The model is also useful because it can be applied to unconventional monetary policy framework which has been the monetary policy trend since the era of the Great Moderation ended. The very same model with a small specification will be used in the next chapter which covers monetary policy in the post-crisis period.

3 Monetary policy in the post-crisis context

3.1 An examination of balance sheets and credit creation

In this subsection, the balance sheets of a central bank and an aggregate private banking sector are examined. It is extremely important to have a clear understanding on both parties' balance sheets as monetary policy measures change the composition of them. This subsection is particularly relevant from the viewpoint of unconventional monetary policy measures. The subsection also introduces and examines the credit creation mechanism, and its two different interpretations. The credit creation explains how deposits are created in the monetary system and it helps to understand reserves in the monetary system.

By adjusting the policy rate in times of conventional monetary policy, the central bank adjusts the amount of bank reserves that are a liability on its balance sheet. As a matter of fact, the central bank must be willing to supply as many reserves as banks demand at that rate [Benes and Kumhof 2012]. The adjustment is typically done by open market operations which means buying or selling government bills and bonds or the usage of repurchase (repo) agreements [Sheard 2013b]. To see and understand this more concretely, let the following section provide an examination of balance sheets.

3.1.1 Balance sheet identities

A simplified balance sheet of the central bank, on the liability side, consists of Reserves (R), banknotes that are in circulation (BK) and government deposits (GD). The asset side consists simply of assets (A). Thus, the balance sheet identity can be written as:

$$A = R + BK + GD$$

or in change terms:

$$\Delta A = \Delta R + \Delta BK + \Delta GD$$

and rearranging for reserves:

$$\Delta R = \Delta A - \Delta BK - \Delta GD.$$

From the rearranged identity the determinants of the aggregated reserves in the monetary system can be seen. Reserves depend positively on the central bank's assets and negatively on banknotes in circulation and government deposits at the central bank. By selling or by buying assets, ΔA, the central bank can adjust the level of reserves keeping all the others fixed. Note also that bank reserves remain parked at the central bank unless the public demand on banknotes in circulation changes or the government deposits changes. [Sheard 2013a].

By examining the balance sheet of the aggregated private banking sector it is noted that bank reserves (R) are on the asset side of the balance sheet. Other asset classes in the highly simplified balance sheet are loans (L) and bond holdings (B). On the liability side there are deposits (D) and the banks' own equity (E). Thus, an identity linking the assets and liabilities can be written as:

$$R + L + B = D + E$$

or in change terms:

$$\Delta R + \Delta L + \Delta B = \Delta D + \Delta E.$$

Now, private bank lending and its effects on the aggregated balance sheet is examined. When a bank makes a new loan, its balance sheet changes simultaneously from both sides; the new loan is on one hand an asset for the bank, but also an offsetting liability as it increases the borrower's deposits [Keister and James 2009]. All other items remain unchanged in the balance sheet identity, namely

$\Delta R = \Delta B = \Delta E = 0$, it follows that $\Delta L = \Delta D$. Note that even loans and deposits are the balance sheet counterparts, the bank does not have to wait for deposits to flow into the bank before lending out; rather the bank creates its own funds, deposits, by lending out [Benes and Kumhof 2012]. In other words, neither the reserves nor the deposits make lending possible or are prerequisite for the bank, but credit creation, as its name indicates, literally creates credit and consequently new deposits (money) come into existence, out of nothing. Thus, loans create new deposits in the banking system, not the other way around and the new deposits must be covered by a certain amount of reserves. [Sheard 2013a]. This will be yet confirmed in the next sub-subsection.

Remembering from the central bank's balance sheet, for reserves to go up either the central bank's assets need to shrink or banknotes in circulation or government deposits need to go up. None of these are directly affected by the bank making a new loan. Thus, when $\Delta B = \Delta D = \Delta E = 0$ it follows that $\Delta L = -\Delta R = 0$. Thus, the link between bank lending and reserves is in the change of banknotes in circulation. All new loans have corresponding deposit items in the balance sheet, but when some of the deposits are withdrawn by the public and hence converted into cash the bank reserves contract. This can be confirmed by looking at the central bank's balance sheet

$$\Delta R = -\Delta BK$$

when all the other items in the central bank's balance sheet remain unchanged, i.e. $\Delta A = \Delta GD = 0$. [Sheard 2013a].

Note that for an individual bank, it is almost impossible to control the link between reserves and loans. It is possible as far as a new loan is being withdrawn and converted into cash by the borrower. But examining the banking sector aggregately it is very likely that the new loan is just moving from a deposit account to another and the reserves remain unchanged. The following conclusion can be drawn: the banking sector even with some excessive reserves, cannot cause a reduction in reserves by initiating new lending. [Sheard 2013a].

By examining the simplified balance sheets of the central bank and the banking sector it can be noted that deposits come from two places which are new lending or from government deficits. Banks create deposits via credit creation by lending money as already described, but another way that produces new deposits is a government running a budget deficit. The greater the deficit is, the larger is the amount

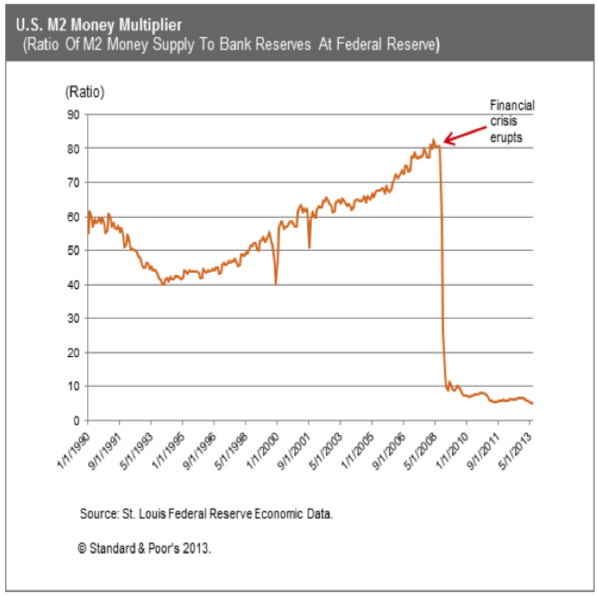

Figure 1:
[Sheard 2013a]

of new deposits the government creates to the system as it puts more money into the public's bank accounts than it takes out. The balance sheets of both instances, when the government is running a deficit, adapt as follows:

$$\Delta D = \Delta R$$

for the banking sector, when all the other balance sheet items remain unchanged, i.e. $\Delta L = \Delta B = \Delta E = 0$. The central bank's balance sheet in turn adapts as follows:

$$\Delta R = -\Delta GD$$

when all the other balance sheet items remain unchanged, i.e. $\Delta A = \Delta BK = 0$. Note, that neither reserves nor deposits are lent out by banks, but new deposits are created by lending or by government deficits. [Sheard 2013a].

The U.S. M2 money multiplier that is a ratio of M2 money supply and reserves collapsed extremely sharply in the the fall of 2008 (See figure 1 on the current page). This was a result of the fact that the denominator of the ratio, i. e. reservers, increased sharply [Sheard 2013a]. The increase of reserves is confirmed by Blinder (2010) and will be returned to the beginning of section 3.2. [Sheard 2013a].

Table 3: The classic textbook representation of money multiplication

	Deposit	1% Reserve requirement	Loanable funds
Bank A	US$100	US$1	US$99
Bank B	US$99	US$0.99	US$98.01
Bank C	US$98.01	US$0.9801	US$97.0299
...	...	...	...
	Maximum amount eventually lent by the banking system		US$9900

As a central bank targets an interest rate, it adjusts the amount of reserves by buying or selling the assets. Remember from the central bank's balance sheet, that if the others remain same then $\Delta A = \Delta R$. When the central bank conducts quantitative easing it provides excess reserves to the private banks. As it was seen, an individual bank cannot lend out excess reserves it may have, so one may ask what is the point of quantitative easing. By conducting quantitative easing, the central bank replaces government bonds and other securities in private banks' balance sheet with fresh deposits and reserves. This pushes yields down and is supposed to make private banks slightly more willing to making new loans (credit creation) as their balance sheet has been rebalanced and after the QE it includes less higher-yielding assets. When the central bank wants to tighten conditions again, it sells assets and thus reserves are extinguished. So it works both ways. [Sheard 2013a].

3.1.2 Credit creation: an essential feature of banking

To complete the examination above, let credit creation yet be demonstrated briefly. The classic representation of credit creation in economics textbooks (see table 3) is based on the view that banks are intermediaries of already existing purchasing power. A typical representation about credit creation is that a bank receives a deposit of US$100, and being imposed to minimum reserve requirement, say, 1%, it deposits US$1 to the central bank and will lend out the remaining US$99. These US$99 may end up to accounts of another bank which also is imposed to the very same reserve requirement and thus it lends only US$98.01 out and deposits US$0.99 to the central bank. And this process will continue as long as a total of US$9900 has been lent out. This representation is successive financial intermediation or "channeling of savings to investors" type of representation as a single bank is unable to create credit. However, the overall banking system in this representation creates money. [Werner 2005].

Another, more accurate representation of credit creation is examined next (See table 4). In this representation every single bank is able to create money "out of nothing". Werner (2005) even uses

Table 4: Credit creation more accurate

Step 1	Assets	Liabilities
		US$100
Step 2	Assets	Liabilities
	US$100	US$100
Step 3	Assets	Liabilities
	US$100	US$100
	US$9900	US$9900

the Compact Oxford English Dictionary's definitions for the words *lend*, *creation* and *create* to obtain support for why lending or intermediating something that already exists is rather creating something out of nothing. The idea of this other representation is in line with, and supported by the balance sheet identities represented in the previous sub-subsection. The first step in this representation is that a bank receives the same initial US$100 deposit and it is recorded as a new liability. Instead of lending US$99 out, the bank uses the entire US$100 to increase its reserves which further implies the asset side of the bank to increase (step 2). Now this US$100 as reserves is 1% of US$10,000. Thus the bank can make new loans equal to the difference between US$10,000 and US$100, namely $9900, and the reserve requirement is met with that US$100 in reserves. In the third and final step, the bank has created a new loan of US$9900 which is an asset to itself but also a corresponding liability as the borrower of the new loan has US$9900 on his or her deposit account. [Werner 2005].

3.1.3 The anatomy of quantitative easing

By adjusting the policy rate, the central bank can encourage or discourage banks to more lending and more money creation (credit creation) in normal times. However, when the (zero) lower bound is reached, another way to stimulate the money creation of banks is to launch a program of asset purchases (QE). This is an alternative way for the central bank to meet its inflation target, but the anatomy and the role of money are different in the two policies. [McLeay et al. 2014].

Quantitative easing, as the name indicates, has the focus on the quantity of money. To demonstrate how QE works, an example that involves one pension fund, one commercial bank and one central bank is examined. Initially, the central bank purchases certain amount of assets from the pension fund that are financed by the creation of broad money and with a corresponding increase in the amount of central bank reserves. Consequently, considering the pension fund, its asset side changes as the bought assets are replaced by newly created deposits by the central bank. [McLeay et al. 2014].

The pension fund has now probably more money relative to other assets, and therefore it wants to use some amount of that money on some higher-yielding assets. By buying these higher-yielding assets the pension fund raises the prices of these assets and respectively lowers the returns and costs to companies of raising funds in these markets. This in turn leads to higher spending and the economy is thus stimulated. An often heard misconception is that by QE measures the central bank is giving "free money" or alternatively providing some extra reserves to the banking system but by this example these are easy to reject. It is rather rebalancing the composition of the balance sheets. [McLeay et al. 2014].

Next, the role of the commercial bank is examined. Note, that the pension fund does not have an account in the central bank, and due to practical reasons the central bank is not buying the assets from the pension fund by cash. The role of the commercial bank is to be an intermediary. The commercial bank, whose client the pension fund is, credits the pension fund's account with the amount of the asset purchase program, and in exchange it gets the assets to be purchased by the central bank (government bonds). Now the central bank gets these assets, which has been its intention from the very beginning, by crediting reserves to the commercial bank that acted as an intermediary. All the balance sheet components are naturally equal by the magnitude. Figure 2 in the next page demonstrates how the balance sheets of each involving party change when the central bank conducts a QE operation. [McLeay et al. 2014].

3.2 A review of events preceding the crisis

The onset of the global financial crisis changed monetary policy substantially. The Fed conducted monetary policy over most of the post-war period by conventional policy measures, i.e. by manipulating the Federal Funds rate [Gertler and Karadi 2011]. However, early in 2008 the Fed began purchasing more illiquid assets and in exchange it provided more liquid T-bills to the private sector. Illiquidity was not necessarily the main problem in the underlying situation; rather it was fears of insolvency [Blinder 2010]. Another initial set of quantitative easing measures occurred on the liability side of the balance sheet as the treasury started to deposit its excess reserves to its central bank accounts. This enabled the Fed to continue with its asset purchases with no fear of running out of T-bills to sell in exchange. In addition, the Fed was able to make more discount window loans, and after the Bear Stearns rescue in March 2008 it began lending to non-bank primary dealers [Blinder 2010].

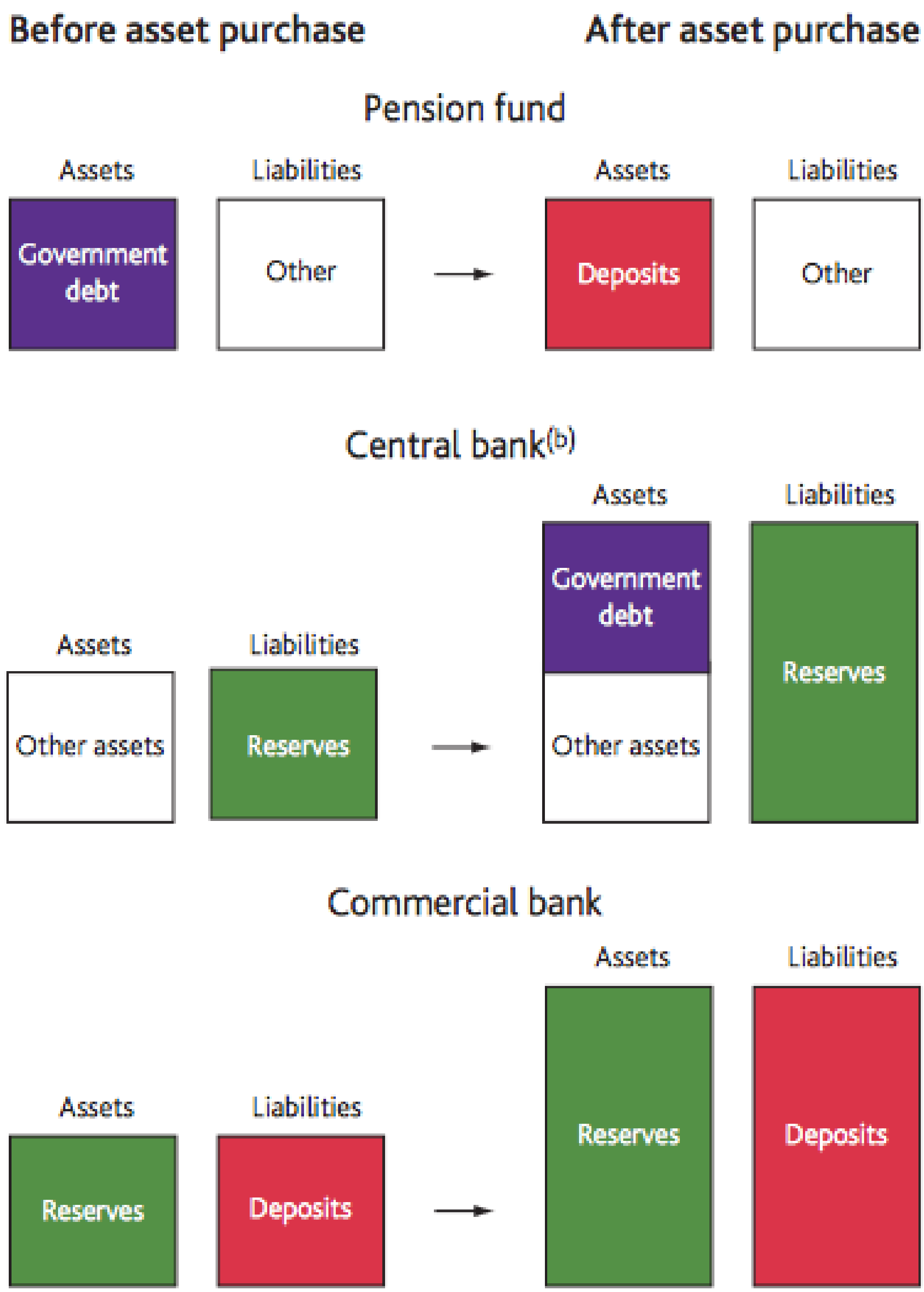

Figure 2:
[McLeay et al. 2014]

The Lehman Brothers failure in mid-September 2008, and the following collapse of the shadow banking system was the final nail in the coffin [Gertler and Karadi 2011]. Quantitative easing measures were not supposed to boost aggregate demand anymore, but rather the situation was "battle stations" as Blinder (2010) describes it. Within a period from September 3 to November 12 in 2008, the asset side of the Fed's balance sheet increased from $907 billion to $2.214 trillion (see figure 3), and the variety of assets in its balance sheet had never been so diverse [Blinder 2010]. Over the same period, the liability side of the balance sheet increased from about $11 billion to $594 billion, and at the end of the year 2008 it was $868 billion. As the Fed's capital stayed almost the same over the same period, the Fed's leverage also increased substantially [Blinder 2010].

Monetary policy conducted by the ECB in the eurozone, was very loose throughout the first years of the 2000s. According to the first pillar of the Maastricht Treaty the broader money M3 should grow about 4,5 % on average on a yearly basis. However, the M3 aggregate grew 106 % during the years of 2001 to 2008. After the year 2007 the growth rate of M3 started to decline and it stayed barely under the 4,5 % target till 2013. Meanwhile lending to the private sector by commercial banks declined even more, whereas pre 2007 it grew in tandem with M3 or even faster, except in the aftermath of the IT-bubble [Kanniainen 2014].

After the crisis erupted, both the Bank of Japan and the Fed tuned their monetary policy to be looser than the zero lower bound policy rate allows via quantitative easing measures [Kanniainen 2014]. The ECB has lowered its policy rate close to zero, but the quantitative easing measures have not yet been as massive as they have been among the other mentioned central banks. The reason behind more passive quantitative easing measures is at least partly disagreements within the governing council of the ECB [FT 2014].

3.3 Unconventional monetary policy in the RBC-model framework

In this sub-section the already familiar RBC-model is examined in the context of unconventional monetary policy and in the situation where the nominal interest rate is set to zero by the central bank. As a reminder, within this RBC-model framework, unconventional monetary policy refers to monetary policy, where the central bank is engaged in purchases of a variety of assets such as mortgage-backed securities and long-term government bonds and thus extends credit to the private economy [Farmer 2012].

Table 5: Assumptions

Time preference	Risk aversion	Probability of staying in state a	Probability of staying in state b	Growth rate in state a	Growth rate in state b
β	ρ	$p_{a,a}$	$p_{b,b}$	$\Delta y(a)$	$\Delta y(b)$
0.97	2.0	0.9	0.95	4%	-5%

Table 6: The effect of changing the zero-inflation target

$\bar{I}$	η	ϕ	$\pi(a)$	$\pi(b)$	$I(a)$	$I(b)$
1.05	2	0	3.4%	-2.4%	12.3%	0%
0.99	2	0	9.3%	0.05%	18.3%	0%

The following calibrated example illustrates why conventional monetary policy becomes problematic at the zero lower bound, and why the central bank must switch to unconventional monetary policy measures. In table 5, there are parameter assumptions for the difference equations (22) which are all the same as in the previous chapter's example, except now the economy shrinks by 5% per year in state b.

These assumptions further imply that the central bank would like to set a negative interest rate in state b, but since the negative interest rate is unthinkable, the policy rule equation (24) must be amended as follows:

$$\psi[\pi(s), \Delta y(s)] = \max[\bar{I}\pi^{\eta}\Delta y^{\phi}, 1]. \tag{25}$$

This rule allows the gross return $(1+i)$ to be no smaller than 1. In other words, whenever the central bank would like to set a negative interest rate it chooses to set the rate to zero instead. Table 6 demonstrates the solutions of the difference equations (22) and (23) with the new assumptions. It also describes two possible monetary policy rules which differ only in the zero-inflation target and they are both imposed by the zero lower bound in state b.

When the central bank follows rule 1 (row 1) there will be deflation of 2.4 % in state b. Now if the central bank switched to rule 2 (row 2) there would be an inflation rate of 0.05%. The difference in inflation across the two rules is enforced by what households expect the central bank to do in future, i.e. what they expect the zero-inflation target and other reaction coefficients to will be in the future. The central bank certainly wants to avoid a situation of deflation and thus it tries to signal credibly its willingness to switch to policy rule 2. [Farmer 2012].

Let it be assumed that the central bank is following rule 1 and the current state of the world is b. It is impossible to signal willingness to change the policy rule (by conventional open market operations) since both rules lead to the very same zero interest rate in state b. Conventional open market operations are inefficient in the zero lower bound as treasury bills and base money become perfect substitutes. [Farmer 2012]. The economy is satiated with liquidity [Svensson 2003].

Remembering that in the equilibrium of this model, current prices are influenced by beliefs about future prices. The central bank can affect current prices by managing households' expectations on its future actions. Even though conventional open market operations become inefficient, there is another way to credibly signal the willingness to change the rule. The other way stems from the fact that even though both rules lead to the zero interest rate in state b, the pricing kernels differ between the rules and that has some helpful consequences. [Farmer 2012].

To see the difference between the pricing kernels, let $Q_1(s, s\prime)$ be the pricing kernel associated with policy rule 1, and $Q_2(s, s\prime)$ be the pricing kernel respectively for rule 2. Then the following equation holds:

$$Q_i(b, a\prime) + Q_i(b, b\prime) = 1 \tag{26}$$

for $i = 1, 2$. The equation tells that the interest rate is zero in state b under both policy rules, but this equation does not hold for each security, meaning that

$$Q_1(b, a\prime) \neq Q_2(b, a\prime)$$

and

$$Q_1(b, b\prime) \neq Q_2(b, b\prime). \tag{27}$$

These two inequalities describe the differences in the prices of the Arrow securities at the zero lower bound across the two policy rules. They further imply that there are some other financial securities than treasury bills that have different prices depending on which rule the central bank is following. As an example, these securities may be long-term government bonds or mortgage-backed securities issued by the private sector. By intervening and targeting its open market operations to these assets, the central bank is able to signal its intention to operate under the other rule in future states. [Farmer 2012].

This calibrated example is interesting as it describes fairly well the situation in the eurozone at the moment. The central interest rates are pushed close to zero, inflation expectations are low, and a fear of deflation exists. Thus the European Central Bank in every way endeavors to increase the expectations, and by various programs such as T-LTRO, it attempts to signal its readiness to provide stimulus to the economy and reach its inflation target that is below, but close to, 2% over the medium term [ECB 2014c]. The same theme will be further developed in chapter 4, where liquidity trap exit strategies and the spiral of deflationary expectations are examined.

3.4 Evidence of the effects of quantitative easing on inflation expectations

This subsection collects and demonstrates some evidence about the effects of unconventional monetary policy measures on inflation expectations in the post-crisis period. The evidence is found by looking at the growth of balance sheets of central banks and swap markets. Eggertsson and Woodford (2003) have argued about the balance sheet composition irrelevance of the central bank (the Fed). However, their irrelevance proposition does not consider that a change in the central bank's balance sheet may signal that the policy rule has changed [Farmer 2012].

The demonstrated evidence covers two western central banks: the Fed and the Bank of England (BoE). In the fall of 2008, following the Lehman Brothers bankruptcy, the balance sheet of the Fed changed rapidly and substantially (see figure 3 on the following page). Figure 3 describes the asset side of the Fed's balance sheet during the period from 2007 to the beginning of the year 2011. The asset side is broken down into three separate components that are: (1) short-term treasury securities, (2) mortgage securities and (3) other securities. The last component consists mainly of loans to the holding company called Maiden Lane that was created for the special purpose of rescuing the financial sector. [Farmer 2012].

The increase of the balance sheet was mainly contributed to by the purchases of mortgage and other securities that pay different amounts in different states. In the light of the RBC-model presented, the Fed did not buy an equal weighted basket of all Arrow securities but it rather bought a basket with very different pay-outs in all different future states [Farmer 2012].

The red line on figure 3 expresses one-year inflation expectations. The expectations are derived from the value of a swap, which can be thought to adequately to describe inflation expectations, as a swap is a contract where there is a payment at the end of the contract period from one party to another.

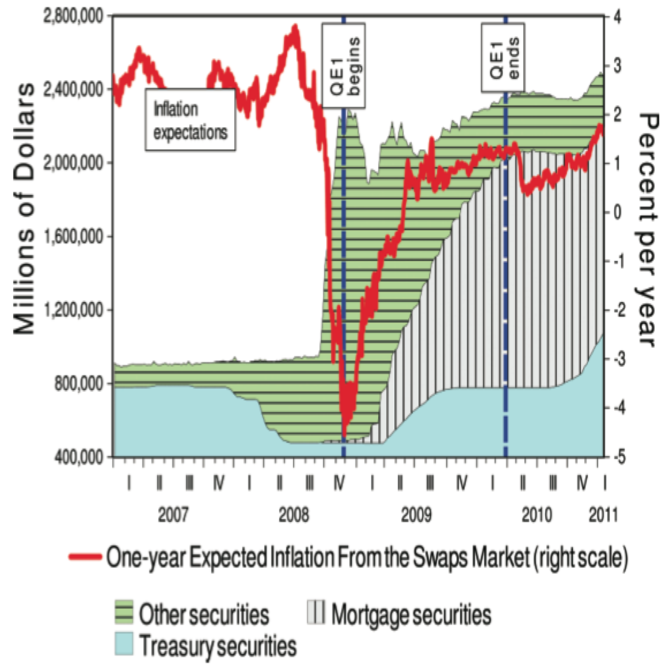

Figure 3:
[Farmer 2012]

The traders of the particular swap were pricing a large expected deflation pre-QE1 but the launch of QE1 brought the expectations back on the positive path. It is hard to see that these movements would be purely coincidental. [Farmer 2012].

The findings of Farmer (2012) are in line with the findings of Hofmann and Zhu (2013). The regression analysis of Hofmann and Zhu (2013) indicates that the effects of the large-scale asset purchases by the Fed and the BoE on inflation expectations have been statistically significant, but their quantitative importance is uncertain. Hofmann and Zhu (2013) also find that inflation expectations in terms of swap values rebounded back to the positive path after the QE-programs were launched in 2008 and 2009. But since only medium and long-term inflation swap rates were statistically significant, they leave an open question that there may be some other main driving factor behind the shifts in inflation expectations.

Figure 4 and 5 by Hofmann and Zhu (2013) demonstrate the balance sheet of the BoE and the inflation swap rates in the United Kingdom. The results are very similar with the results in figure 3.

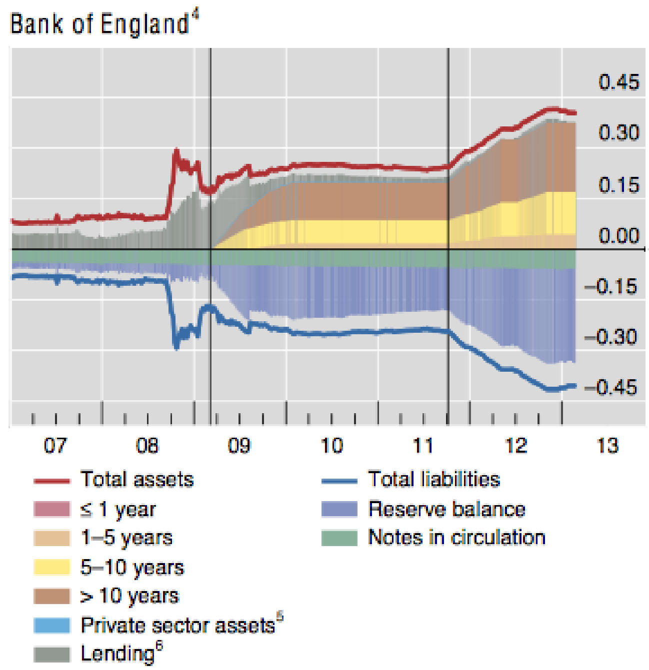

Figure 4:
[Hofmann and Zhu 2013]

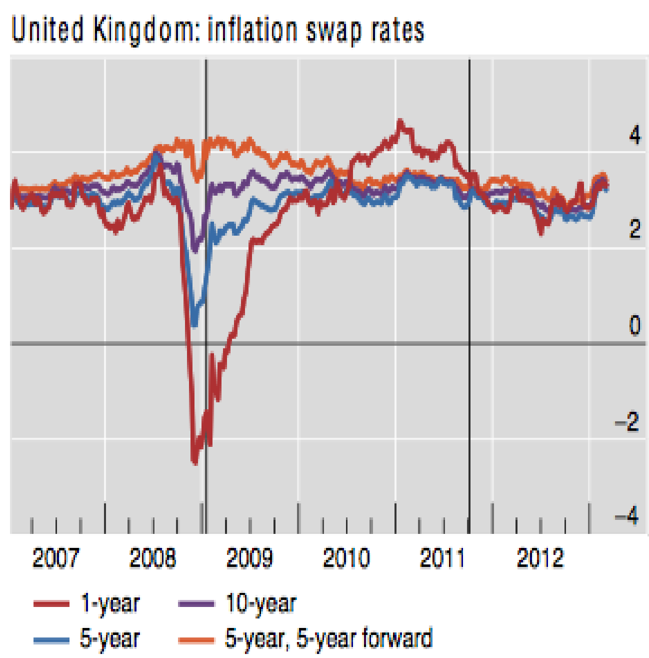

Figure 5:
[Hofmann and Zhu 2013]

3.5 A state-of-the-art DSGE-model of unconventional monetary policy

In this sub-section a quantitative monetary model that fits extremely well to the post-crisis context is examined. The model is a state-of-the-art type of DSGE model constructed by Gertler and Karadi (2011) and its baseline framework is built on the DSGE-models of Christiano et al. (2005) and Smets and Wouters (2007). First of all, it incorporates financial market frictions. Earlier quantitative models of conventional monetary policy e.g. Smets and Wouters (2007) or Christiano et al. (2005) assume that financial markets are frictionless. Secondly, it considers a direct central bank intermediation as an explicit tool of monetary policy, whereas earlier models that allow frictions do not share this feature. Finally, the model is more advanced and more realistic than its contemporaries as it allows financial intermediaries to face endogenously determined balance sheet constraints via an agency problem between financial intermediaries and their depositors. [Gertler and Karadi 2011].

The model incorporates all the other basic features of a DSGE monetary model such as nominal rigidities. The model consists of five different types of agents: households, financial intermediaries, non-financial goods producers, capital producers and monopolistically competitive retailers. Financial intermediaries transfer funds between households and non-financial firms. Monopolistically competitive retailers attendance in the model guarantees nominal rigidities. [Gertler and Karadi 2011].

The central bank in the model can conduct either conventional or unconventional monetary policy. Unconventional monetary policy is captured so that the central bank can act as an intermediary by borrowing from savers and lending to investors. The central bank's credit injection may be necessary in times of huge financial distress. Being unconstrained by its balance sheet and leverage ratio it may sufficiently boost credit flows in the economy. The model incorporates a disturbance shock to the quality of capital that causes a significant capital loss in the financial sector. This may tighten private credit and cause a demand for a central bank intervention. [Gertler and Karadi 2011].

This DSGE-model is broadly discussed in this thesis, even though it does not provide in itself a straightforward framework to analyze the effects of monetary policy measures on inflation expectations. Despite this fact, it is very relevant as it mimics some features that were behind the eruption of the global financial crisis. It is also introduced due to its state-of-the-art nature; this particular model by Gertler and Karadi (2011) is much referred to in monetary economics literature. Moreover, by introducing this model, the previous two models are complemented with yet another kind of intertemporal dynamic stochastic general equilibrium model. [Gertler and Karadi 2011]. In the following section, the model is characterized element by element.

3.5.1 Household characterization

Households are continuously countable and identical which supply labor, consume and save. Saving happens via two channels: by lending to the government or to competitive financial intermediaries. There are two types of members in *each* household: workers and bankers. Both of them work and return all possible earnings back to their household. Bankers are the managers of financial intermediaries. Thus, a household effectively owns an intermediary that is managed by its banker, but also, the deposits of the respective household are held in *another* intermediary. Within each family, perfect consumption insurance exists among the family members which further implies that each member faces an idiosyncratic shock to income analogously. The heterogeneity assumption enables an introduction of financial intermediation in a meaningful way. [Gertler and Karadi 2011].

A fraction f of the household members are bankers and a fraction $1-f$ are workers at any moment in time t. Individuals may change between the occupations over time. A current banker stays as a banker in the subsequent period with probability θ, which is independent on past occurrences. Consequently, a current banker stays as a banker in two periods with probability θ^2, stays as a banker in three periods with probability θ^3 and so on. The geometric sum of the sequence is $\frac{1}{1-\theta}$ which is the average survival time for a banker in any given period. In each period $(1-\theta)f$ bankers exit the business and become workers. The relative proportion of each type of workers, however, stays fixed as a similar number of current workers randomly become bankers. Exiting bankers leave attained earnings to their respective households and the new bankers are promoted with start up funds by the households. [Gertler and Karadi 2011].

Consumption is denoted by C_t and family labor supply is denoted by L_t. Household preferences are given as:

$$\max E_t \sum_{i=0}^{\infty} \beta^i \left[ln(C_{t+i} - hC_{t+i-1}) - \frac{\chi}{1+\varphi} L_{t+i}^{1+\varphi} \right] \tag{28}$$

with a discount rate $0 < \beta < 1$; habit formation parameter $0 < h < 1$, relative utility weight of labor $\chi > 0$ and inverse Frisch elasticity of labor supply $\varphi > 0$. The model allows habit formation as in Christiano et al. (2005) and Smets and Wouters (2007) to capture consumption dynamics. [Gertler and Karadi 2011].

Finances of a household are formulated next. In equilibrium, there are two riskless instruments for the household that are perfect substitutes, namely intermediary deposits and government debt. Both of them are one-period by maturity and pay the gross real return R_t from time $t-1$ to t. The total quantity of short-term government debt the household purchases, is denoted by B_{t+1}. The real wage is denoted by W_t; net payouts to the household from ownership of *all* types of firms are denoted by Π_t; and the lump sum taxes are denoted by T_t. Consequently, the budget constraint of the household is given as:

$$C_t = W_t L_t + \Pi_t + T_t + R_t B_t - B_{t+1}. \tag{29}$$

Note that Π_t represents the net transfer the household gives to its members that enter banking at time t. Also, it does not matter within the model whether the household holds government debt directly or indirectly via financial intermediaries. [Gertler and Karadi 2011].

The marginal utility of consumption is denoted by ϱ_t, and the standard first order conditions for labor supply and consumption/saving:

$$\varrho_t W_t = \chi L_t^{\varphi} \tag{30}$$

with

$$\varrho_t = \frac{1}{(C_t - hC_{t-1})} - \frac{\beta h E_t}{(C_{t+1} - hC_t)}$$

and

$$E_t \beta \Lambda_{t,t+1} R_{t+1} = 1 \tag{31}$$

with

$$\Lambda_{t,t+1} \equiv \frac{\varrho_{t+1}}{\varrho_t}.$$

[Gertler and Karadi 2011].

3.5.2 Financial intermediaries characterization

Financial intermediaries represent the entire banking sector including investment banks and commercial banks. They channel funds from savers to investors, and are engaged in maturity transformation. The balance sheet of an intermediary consists of long-term assets, and they are funded by short-term liabilities beyond their own equity capital. [Gertler and Karadi 2011].

The net equity wealth or worth of an intermediary j at the end of period t is denoted by N_{jt}. Another liability - the debt capital - is denoted by B_{jt+1} and that is household deposits upon which the intermediary pays the gross real return R_{t+1} at time $t+1$. On the asset side of the balance sheet, S_{jt} depicts the quantity of financial claims on non-financial firms that the intermediary holds and Q_t depicts the relative price of them. The assets of the intermediary yield a stochastic return R_{kt+1} which is endogenously determined as is R_{t+1} also. The balance sheet identity of an intermediary j can be written as:

$$Q_t S_{jt} = N_{jt} + B_{jt+1} \tag{32}$$

and the equity capital of the intermediary evolves over time as:

$$N_{jt+1} = R_{kt+1} Q_t S_{jt} - R_{t+1} B_{jt+1} = (R_{kt+1} - R_{t+1}) Q_t S_{jt} + R_{t+1} N_{jt}. \tag{33}$$

Consequently, the equity capital evolution is determined by the premium $(R_{kt+1} - R_{t+1})$ the intermediary earns on its assets and the total quantity of its assets QS_{jt}. [Gertler and Karadi 2011].

An intermediary discounts both the returns of assets and the cost of liabilities. It will fund only the assets which discounted returns exceed the discounted costs of borrowing. A stochastic discount factor $\beta^i \Lambda_{t,t+i}$ is applied at time t to the earnings at period $t+i$. Consequently:

$$E_t \beta^i \Lambda_{t,t+1+i}(R_{kt+1+i} - R_{t+1+i}) \geq 0, i \geq 0.$$

In the perfect capital markets the relation holds with equality as the risk-adjusted premium is zero. However, with imperfect capital markets the discounted risk adjusted premium may be positive. As long as the intermediary is able to make positive profits that exceed the return on household deposits it provides funds for the banker to acquire more assets till he or she exits the industry. Thus, the banker maximizes the expected terminal wealth:

$$V_{jt} = \max E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i}(N_{jt+1+i})$$

and by substituting equation (33) to this:

$$V_{jt} = \max E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i}[(R_{kt+1+i} - R_{t+1+i}) Q_{t+i} S_{jt+i} + R_{t+1+i} N_{jt+i}]. \tag{34}$$

[Gertler and Karadi 2011].

The intermediary wants to expand its assets indefinitely by borrowing additional funds from households as long as the risk adjusted premium is positive. A moral hazard problem is introduced to set limits on this development. At any period, a fraction λ of the amount of available funds, is channeled back to the household by a banker rather than used to the intermediary's investments. For the banker there is a cost of this repatriation as the depositors may force the intermediary to bankrupt and thereby be recovered by the remaining fraction $1-\lambda$ of assets. However, demanding to be recovered with the fraction λ also is too costly for the depositors. [Gertler and Karadi 2011].

The following incentive constraint must be satisfied in order that lenders are willing to supply funds for the banker:

$$V_{jt} \geq \lambda Q_t S_{jt} \tag{35}$$

where the left hand side is the cost of repatriation and the right hand side is the gain of doing it. Furthermore, V_{jt} can be expressed as:

$$V_{jt} = \nu_t Q_t S_{jt} + \eta_t N_{jt} \tag{36}$$

with

$$\nu_t = E_t\{(1-\theta)\beta\Lambda_{t,t+1}(R_{kt+1} - R_{t+1}) + \beta\Lambda_{t,t+1}\theta x_{t,t+1} v_{t+1}\}$$

and

$$\eta_t = E_t\{(1-\theta) + \beta\Lambda_{t,t+1}\theta z_{t,t+1}\eta_{t+1}\}$$

where $x_{t,t+i} \equiv \frac{Q_{t+i}S_{jt+i}}{Q_t S_{jt}}$ is the gross growth rate of the assets between periods t and $t+i$, and $z_{t,t+i} \equiv \frac{N_{jt+i}}{N_{jt}}$ is the gross growth rate of net worth. The interpretations of ν_t and η_t are to be marginal gains and values: ν_t is the expected discounted gain of expanding assets $Q_t S_{jt}$ by one unit while N_{jt} remains constant, whereas η_t is the expected discounted value of having additional unit of N_{jt} while S_{jt} remains constant. In perfect capital market ν_t is zero as intermediaries expanded borrowing will adjust the rate of returns in such a way. The introduced agency problem will set limits on this arbitrage and if the incentive constraint is binding then the intermediary's assets are constrained by its equity capital. [Gertler and Karadi 2011].

The incentive constraints with ν_t and η_t can be written as:

$$\eta_t N_{jt} + \nu_t Q_t S_{jt} \geq \lambda Q_t S_{jt} \tag{37}$$

and if this binds then the assets the intermediary can acquire depends on its equity capital as:

$$Q_t S_{jt} = \frac{\eta_t}{\lambda - \nu_t} N_{jt} = \phi_t N_{jt} \tag{38}$$

where ϕ_t is the ratio of privately intermediated assets to equity, which will be referred to as (private) leverage ratio from now on. Keeping N_{jt} fixed and expanding S_{jt} raises the banker's incentive to repatriate funds. The equation (38) set limits "to the intermediaries leverage ratio to the point where the banker's incentive to cheat is exactly balanced by the cost" and this is how the agency problem leads to an endogenous capital constraint, which undermines intermediary's ability to acquire assets. Note that the equation (38) is binding only if $0 < \nu_t < \lambda$ given that $N_{jt} > 0$ and $\upsilon_t > 0$. In the equilibrium of the model, with reasonable parameter values, the constraint binds "within a local region of the steady state". [Gertler and Karadi 2011].

The banker's net worth evolves as:

$$N_{jt+1} = [(R_{kt+1} - R_{t+1})\phi_t + R_{t+1}]N_{jt} \tag{39}$$

and in addition:

$$z_{t,t+1} = \frac{N_{jt+1}}{N_{jt}} = (R_{kt+1} - R_{t+1})\phi_t + R_{t+1}$$

and

$$x_{t,t+1} = \frac{Q_{t+1} S_{jt+2}}{Q_t S_{t+1}} = (\frac{\phi_{t+1}}{\phi_t})(\frac{N_{jt+1}}{N_t}) = (\frac{\phi_{t+1}}{\phi_t}) z_{t,t+1}.$$

The total intermediary demand of assets can be summed across all individual demands as all the components of the leverage ratio ϕ do not depend on firm-specific factors. Consequently it is obtained:

$$Q_t S_t = \phi_t N_t \tag{40}$$

where S_t is the aggregate quantity of intermediary assets and N_t is the aggregate intermediary capital. The aggregate intermediary capital term is interesting in the general equilibrium of the model: variation in N_t causes variation in overall asset demand and a financial distress pushes N_t heavily down.

[Gertler and Karadi 2011].

The equation of motion is derived next for net equity N_t. The net equity consists of the new worth of existing intermediaries N_{et} and the net worth of new entering intermediaries N_{nt} (bankers). Consequently:

$$N_t = N_{et} + N_{nt}. \tag{41}$$

The fraction θ of bankers survive from $t-1$ to t and thus N_{et} is given by

$$N_{et} = \theta[(R_{kt} - R_t)\phi_{t-1} + R_t]N_{t-1}. \tag{42}$$

It is noted that N_{et} mostly variates due to the fluctuations of R_{kt} and the leverage ratio ϕ_t. [Gertler and Karadi 2011].

New entering intermediaries obtain start up funds from their respective households. The amount of the start up funds are modeled to be a small fraction of the value of the assets that existing bankers intermediated in their final operating period. As the exit probability θ is i.i.d., the total final period assets of existing bankers at time t is $(1-\theta)Q_tS_{t-1}$. The fraction $\frac{\omega}{(1-\theta)}$ from this is transferred by the households to the entering bankers. Thus it follows that aggregately:

$$N_{nt} = \omega Q_t S_{t-1}. \tag{43}$$

The equation of motion for net equity N_t can be finally written as:

$$N_t = \theta[(R_{kt} - R_t)\phi_{t-1} + R_t]N_{t-1} + \omega Q_t S_{t-1}. \tag{44}$$

The parameter ω pushes down the steady state leverage ratio $\frac{QS}{N}$. In the calibrations of the model it will be very small to match this (see table 5). [Gertler and Karadi 2011].

3.5.3 Credit policy characterization

The total value of privately intermediated assets Q_tS_{pt} was defined in the previous sub-subsection. From now on, it is considered that the central bank is also willing to participate in lending activities. Let Q_tS_{gt} depict the amount of assets that are intermediated publicly. Consequently, the total value of intermediated assets is:

$$Q_t S_t = Q_t S_{pt} + Q_t S_{gt}. \tag{45}$$

The central bank's credit policy happens as follows: it issues riskless R_{t+1} interest-paying government bonds that are acquired by households. Then it lends the obtained funds to non-financial firms with the market rate R_{kt+1}. Moreover, it is assumed that the public sector participation in lending has an efficiency cost, τ, per unit of supplied credit. It reflects both the costs of raising funds via government debt and costs for the central bank to identify preferable private sector investments. On the other hand there does not exist an agency problem between the lender and depositors. The public sector always honors its debt and is consequently unconstrained in lending. [Gertler and Karadi 2011].

An equivalent credit policy formulation can be made. Within the alternative formulation the central bank issues the bonds but, instead of household acquisition, financial intermediaries acquire the bonds and fund them by issuing deposits to households. The previously introduced agency problem is valid only to the private assets. Consequently, financial intermediaries are unconstrained in funding of government debt as deposits and government bonds are perfect substitutes by assumption. The equilibrium conditions will be exactly the same regardless of whichever characterization is used. In any case, the central bank is elastically able to issue government debt in order to fund private assets. The alternative characterization gives an interpretation for the holdings of government debt: they are, as a matter of fact, interest-bearing reserves. [Gertler and Karadi 2011].

Let a fraction ψ_t describe the intensity of - the amount of intermediated assets - the central bank is willing to fund. Consequently,

$$Q_t S_{gt} = \psi_t Q_t S_t. \tag{46}$$

The right hand side of the equation is funded by government bonds B_{gt}. By intermediating, the government earns revenue $(R_{kt+1} - R_{t+1})B_{gt}$ at any period t and this will be a component at the revenue side of the government's budget constraint. [Gertler and Karadi 2011].

As privately intermediated funds are constrained by the net worth of the intermediary the equation (45) is rewritten as:

$$Q_t S_t = \phi_t N_t + \psi_t Q_t S_t = \phi_{ct} N_t \tag{47}$$

where ϕ_t is (private) leverage ratio for privately intermediated funds, and ϕ_{ct} is the combined (private + public) leverage ratio for total intermediated funds. The combined leverage ratio can be expressed as:

$$\phi_{ct} = \frac{1}{1-\psi_t}\phi_t. \tag{48}$$

Note that the combined leverage ratio ϕ_{ct} depends positively on the intensity of credit policy. [Gertler and Karadi 2011].

3.5.4 Intermediate goods firms characterization

Intermediate goods firms are competitive non-financial firms. They produce intermediate goods that will be later sold to retail firms. At the end of every period t a representative of this sector acquires capital K_{t+1} that will be usable in the subsequent period. Having utilized the capital in production, the firm may sell the capital in the open market. Adjustment costs of selling are ignored at the firm level. [Gertler and Karadi 2011].

Financial intermediaries finance the capital acquisitions of intermediate goods firms. For every unit of acquired capital K_{t+1} the firm issues S_t claims and prices each claim equal to the cost of unit of capital Q_t. Thus, by arbitrage, the value of acquired capital equals to the value of claims against this capital:

$$Q_t K_{t+1} = Q_t S_t. \tag{49}$$

A presumption is made that funding between financial intermediaries and intermediate goods firms are frictionless. In other words, financial intermediaries perfectly know their clients. However, financial intermediaries were constrained in terms of obtaining funding from households and that constraint has an impact on the amount of funds that are available to intermediate goods firms. This further influence on the required rate of return on capital these firms must pay. Apart from the small effect in required rate of return, the frictionless condition implies that an intermediate goods firm is able to offer a perfect state-contingent security to an intermediary. [Gertler and Karadi 2011].

The intermediate goods production at time t is given in the familiar Cobb-Douglas form by:

$$Y_t = A_t(U_t \xi_t K_t)^{\alpha} L^{1-\alpha}. \tag{50}$$

The production Y_t is obtained by using some combination of capital K_t and labor L_t. A_t stands for the total factor productivity as usual, ξ_t depicts the quality of capital and is meant to bring some exogenous variation to the value of capital and U_t depicts the utilization rate of the capital. Note that $\xi_t K_t$ is the effective quantity of capital at time t and the interpretation of ξ_t, in this context is, that it describes an economic depreciation or obsolescence of capital. However, the market value of an effective unit of capital Q_t is determined endogenously. [Gertler and Karadi 2011].

The price of the output of intermediate goods is P_{mt} and it is assumed that the replacement price of depreciated used capital is fixed at unity. It follows that at time t the firm chooses the utilization rate:

$$P_{mt}\alpha\frac{Y_t}{U_t} = \delta'(U_t)\xi_t K_t \tag{51}$$

and labor demand:

$$P_{mt}(1-\alpha)\frac{Y_t}{L_t} = W_t. \tag{52}$$

As the intermediate goods firms make zero profits and pays its ex post return to capital to the intermediary it follows that the intermediary asset return R_{kt+1} can be written as:

$$R_{kt+1} = \frac{[P_{mt+1}\alpha\frac{Y_{t+1}}{\xi_{t+1}K_{t+1}} + Q_{t+1} - \delta(U_{t+1})]\xi_{t+1}}{Q_t}. \tag{53}$$

The capital that is left over is $(Q_{t+1} - \delta(U_{t+1}))\xi_{t+1}K_{t+1}$ as the replacement price of depreciated capital was fixed at unity. Note that the valuation shock ξ_{t+1} moves the price and return of capital. Also, the current price and return is in general dependent on beliefs about the future path of the valuation shock. [Gertler and Karadi 2011].

3.5.5 Capital producing firms characterization

Capital producing firms buy capital from intermediate goods firms at the end of any period t: they repair depreciated capital and build new fresh capital after which they sell each. The value of new capital is Q_t by unit. It is assumed that households own capital producing firms and receive all the profits they make. The replacement price of depreciated capital was fixed at unity whereas refurbishing capital is costless. However, producing new capital is assumed to be associated with flow adjustment costs. [Gertler and Karadi 2011].

In order to formulate discounted profits for a capital producer, let I_t be gross capital created, $I_{nt} \equiv I_t - \delta(U_t)\xi_t K_t$ be net capital created, and I_{ss} stands for the steady state investment. Consequently, discounted profits are then given by:

$$\max E_t \sum_{\tau=t}^{\infty} \beta^{T-t} \Lambda_{t,\tau} \{(Q_\tau - 1) I_{n\tau} - f\left(\frac{I_{n\tau} + I_{ss}}{I_{n_{\tau-1}} + I_{ss}}\right)(I_{n\tau} + I_{ss})\} \tag{54}$$

with

$$I_{nt} \equiv I_t - \delta(U_t)\xi_t K_t$$

where $f(1) = f'(1) = 0$ and $f'' > 0$ and where $\delta(U_t)\xi_t K_t$ is the capital that is repaired. Flow adjustment costs of investment are allowed but they depend on the net investment flow. Consequently capital producing firms may earn some profits outside the steady state investment level, but it is assumed that any such profit will be channeled back to households as a lump sum. All capital producers choose exactly the same net investment rate and therefore I_{nt} is not indexed producer by producer. The first order condition for investment gives:

$$Q_t = 1 + f(\cdot) + \frac{I_{nt} + I_{ss}}{I_{nt-1} + I_{ss}} f'(\cdot) - E_t \beta \Lambda_{t,t+1} \left(\frac{I_{nt+1} + I_{ss}}{I_{nt} + I_{ss}}\right)^2 f'(\cdot) \tag{55}$$

[Gertler and Karadi 2011].

3.5.6 Retail firms characterization

The input of retail firms is the output of intermediate goods firms. Retailers produce the final output simply by re-packaging the intermediate output; one unit of intermediate output makes a unit of retail output. The final output composite Y_t is a CES[4] type of function; it is a continuum of mass unity of differentiated retail firms as follows:

$$Y_t = \left[\int_0^1 Y_{ft}^{(\epsilon-1)/\epsilon} df\right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{56}$$

where Y_{ft} is output by retailer f. The final output costs are minimized by users:

$$Y_{ft} = (\frac{P_{ft}}{P_t})^{-\epsilon} Y_t \tag{57}$$

and

$$P_t = \left[\int_0^1 P_{ft}^{1-\epsilon} df\right]^{\frac{1}{1-\varepsilon}} \tag{58}$$

[4] Constant Elasticity of Substitution

As in the re-packing process, one unit of intermediate output makes a unit of retail output, the marginal cost is the relative intermediate output price P_{mt}. Nominal rigidities are introduced as in Christiano et al. (2005) so that in every period a firm is able to freely adjust its price with probability $1-\gamma$ and between the periods the firm is able to index its price to the lagged rate of inflation. A retailer then chooses a reset price P_t^* to solve:

$$\max E_t \sum_{i=0}^{\infty} \gamma^i \beta^i \Lambda_{t,t+i} \left[\frac{P_t^*}{P_{t+i}} \prod_{k=1}^{i} (1+\pi_{t+k-1})^{\gamma_p} - P_{mt+i} \right] Y_{ft+i} \tag{59}$$

where π_t is the rate of inflation from period $t-i$ to period t. The first order necessary conditions are given by E_t as:

$$\sum_{i=0}^{\infty} \gamma^i \beta^i \Lambda_{t,t+i} \left[\frac{P_t^*}{P_{t+i}} \prod_{k=1}^{i} (1+\pi_{t+k-1})^{\gamma_p} - P_{mt+i} \right] Y_{ft+i} = 0 \tag{60}$$

with

$$\mu = \frac{1}{1-\frac{1}{\varepsilon}}$$

and by the law of large numbers, the price level of the final output evolves as:

$$P_t = [(1-\gamma)(P_t^*)^{1-\varepsilon} + \gamma(\Pi_{t-1}^{\gamma_p} P_{t-1})^{1-\varepsilon}]^{\frac{1}{(1-\varepsilon)}}. \tag{61}$$

[Gertler and Karadi 2011].

3.5.7 Resource constraint and government policy characterization

Output equals consumption, investment, government consumption and expenditures on government intermediation ($\tau\psi_t Q_t K_{t+1}$). Government expenditures are exogenously fixed at the level G by assumption. Accordingly, the resource constraint of the economy can be written as:

$$Y_t = C_t + I_t + f\left(\frac{I_{nt}+I_{ss}}{I_{nt-1}+I_{ss}}\right)(I_{nt}+I_{ss}) + G + \tau\psi_t Q_t K_{t+1} \tag{62}$$

and the evolution of capital is described by:

$$K_{t+1} = \xi_t K_t + I_{nt}. \tag{63}$$

Lump sum taxes and government intermediation are used to finance the expenditures of the government:

$$G + \tau\psi_t Q_t K_{t+1} = T_t + (R_{kt} - R_t) B_{gt-1} \tag{64}$$

where government bonds B_{gt-1} finance total government intermediated assets $Q_t\psi_{t-1}S_{t-1}$. [Gertler and Karadi 2011].

Monetary policy is characterized by a conventional Taylor rule as follows:

$$i_t = (1-\rho)[i + \kappa_\pi \pi_t + \kappa_y(\log Y_t - \log Y_t^*)] + \rho i_{t-1} + \varepsilon_t \tag{65}$$

where i_t is the nominal interest rate, i is the steady state nominal rate and Y_t is the natural level of output. Yet ρ is the smoothing parameter between zero and one, and ε_t is an exogenous shock to monetary policy. The Fisher equation connects nominal and real interest rates as:

$$1 + i_t = R_{t+1}\frac{E_t P_{t+1}}{P_t}. \tag{66}$$

[Gertler and Karadi 2011].

The above Taylor rule (eq. 65) describes monetary policy well in normal times, but in the occurrence of financial distress and public credit policy intervention the following feedback rule is needed:

$$\psi_t = \psi + \nu E_t[(\log R_{kt+1} - \log R_{t+1}) - (\log R_k - \log R)]. \tag{67}$$

The feedback rule attaches the movements in credit spreads to the sensitivity of public credit policy intervention. If the credit spreads increase from its steady state value, the central bank injects credit in relation to the steady state value of publicly intermediated assets ψ. The term $\log R_k - \log R$ is the steady state premium and the feedback parameter is positive. Also, the smoothing parameter ρ is set equal to zero in crisis situation as the central bank's ability to manage expectations is diminished. By setting it to zero the current interest rate is adjusted at a faster pace. [Gertler and Karadi 2011].

3.5.8 Analysis and the results of the model

As the model is now entirely constructed, some calibrations and experiments of the model are introduced. The baseline model has 18 different parameters altogether, of which fifteen are conventional and the three financial sector parameters λ, ξ, θ are specific to this model. Gertler and Karadi (2011) mostly use estimates from Primiceri et al. (2006) for conventional parameters. The three financial sector parameters are suggestive by nature and the intention of Gertler and Karadi (2011) is to hit the following three targets with these parameters: *"a steady state interest rate spread of one hundred basis*

Table 7: parameter estimates

Households		
β	0.990	Discount rate
h	0.815	Habit parameter
χ	3.409	Relative utility weight of labor
φ	0.276	Inverse Frisch elasticity of labor supply
Financial Intermediaries		
λ	0.381	Fraction of capital that can be diverted (repatriation rate)
ω	0.002	Proportional transfer to the entering bankers
θ	0.972	Survival rate of the bankers
Intermediate goods firms		
α	0.330	Effective capital share
U	1.000	Steady state capital utilization rate (normalized)
$\delta(U)$	0.025	Steady state depreciation rate
ζ	7.200	Elasticity of marginal depreciation with respect to utilization rate
Capital producing firms		
η_i	1.728	Inverse elasticity of net investment to the price of capital
Retail firms		
ε	4.167	Elasticity of substitution
γ	0.779	Probability of keeping prices fixed (rigidity parameter)
γ_p	0.241	Price indexing parameter
Government		
κ_π	1.5	Inflation coefficient of the Taylor rule
κ_y	$\frac{0.5}{4}$	Output gap coefficient of the Taylor rule
ρ_i	0.8	Smoothing parameter of the Taylor rule
$\frac{G}{\bar{Y}}$	.200	Steady state proportion of government expenditures

points; a steady state leverage ratio of four; and an average horizon of bankers of a decade." Table 7 summarizes the parameters and their respective estimates.

With the listed parameters Gertler and Karadi (2011) make several experiments of which particularly the crisis experiments are interesting in the light of this thesis as they mimic some of the basic features that led to the global financial crisis. The crisis experiments are associated with both public sector credit policy intervention and the impact of the zero lower bound on nominal interest rates. Only the relevant experiments in the light of this thesis are introduced here. [Gertler and Karadi 2011].

In the crisis experiment, an initial exogenous shock induces a decline in the capital quality. The disturbance shock is a rare event, but once it appears, it obeys an AR(1) process[5]. Also, the initial shock is adjusted to be comparable by its magnitude with the global financial crisis. The main idea of the crisis experiment is to capture a situation, where the capital quality decline is associated with intermediary asset deterioration causing a decrease in the net worth of the intermediaries. Consequently, asset

[5] See more about AR(1) process e.g. from Verbeek (2008)

prices and investments are reduced. As the asset price (Q_t) falls, the endogenous fall in Q_t further amplifies the deterioration. This is the endogenous second round effect. The high degree of leverage also influence on the overall magnitude of the balance sheet deterioration. [Gertler and Karadi 2011].

The crisis experiment is first examined ignoring a central bank credit policy intervention and the zero lower bound constraint. Given this, the initial exogenous shock causes only a modest decline in output when the financial intermediation process is yet assumed to be frictionless. But when the frictions in the intermediation process are taken into account there is a sharp recession associated with intermediary asset deterioration, a firesale of assets, capital market price decline, intermediary capital shrinkage and an increased spread in risk premia. The initial decline in output is 3 % relative to the trend and it further shrinks to 6 % until it recovers to the trend level five years after the shock. In addition, the model captures the slowing effect of deleverage of financial institutions to the recovery of the economy. [Gertler and Karadi 2011].

Next the crisis experiment is examined acknowledging a central bank credit intervention but yet ignoring the zero lower bound. Two different intervention intensities associated with $\nu = \{10, 100\}$ in the feedback rule (eq. 67) are studied. The smaller intensity value is roughly in proportion to the intensity of the actions of the Fed in the crisis measured in terms of the absorbed assets in proportion to total assets in the economy. The central bank intervention moderates the economic downturn significantly in both cases. The intervention dampens the rise in the spread which in turn dampens the investment decline. The lighter intervention is associated with an increase in the central bank's balance sheet, by its magnitude around 7 %. The more aggressive intervention ($\nu = 100$) is even more recoverable but it also requires the central bank lending to be about 15% of the capital stock. Within each case, the central bank is assumed to exit from its balance sheet slowly over time as the private financial intermediaries get recapitalized. The exit will take 5 and 15 years respectively. [Gertler and Karadi 2011].

In terms of inflation the central bank intervention seems to be kind of neutral. Despite the large increase in the central bank's balance sheet, inflation remains relatively stable and deflation is prevented by stimulating central bank measures [Gertler and Karadi 2011].

The same examination is yet done with the zero lower bound constraint. In the baseline crisis experiment the nominal interest rate drops over 5% which violates the zero lower bound on the nominal rate as the steady state value of the model is 400 basis points (i.e. 4%). Disabling the nominal interest rate to fall below zero, the output decline is roughly 25% larger than in the previous examination. Being incapable to lower the interest rate sufficiently causes more financial distress and larger movements in the spread and the contraction is further enhanced. Considering the central bank intervention in this case the relative gains from the central bank intervention are remarkable as the inflation rate drops less and output reduction is subdued. [Gertler and Karadi 2011].

On the basis of the analysis of this model a following conclusion can be drawn: unconventional monetary policy is helpful in crisis situations. In the occurrence of a crisis, the balance sheet unconstrained central bank can ease credit policy in the economy. The intervention is beneficial regardless of whether the zero lower bound binds or not. If the zero lower bound binds the intervention is more desired. As the crisis situation returns back to normal over time and private financial intermediaries become recapitalized, the benefits from unconventional monetary policy slowly diminish. This follows from the fact that financial intermediaries are more efficient in making loans. [Gertler and Karadi 2011].

The results and analysis of the introduced model by Gertler and Karadi (2011) find support from the findings of the model by Curdia and Woodford (2010). The Curdia and Woodford 2010 paper constructs an extended New-Keynesian model, where the central bank's balance sheet has a role in equilibrium determination. The analysis of the model indicates that central bank credit policy or asset purchase programs have a role, in particular when the private financial markets are impaired, but as in the model of Gertler and Karadi (2011) central bank credit policy has substantial benefits only at times of unusual financial distress [Curdia and Woodford 2010].

4 The liquidity trap: an unwelcome problem of monetary policy

4.1 An unreasonably high real interest rate

This chapter examines various options for the central bank to escape an unwelcome situation known as a liquidity trap. The chapter is motivated by the persistently low inflation rate in the eurozone and the potential threats this may bring to the development of the eurozone economy. A definition of a liquidity trap has come to mean a situation in which the nominal interest rate hits its zero lower bound. However, that definition differs from the Keynes's original meaning of a liquidity trap. The Keynesian liquidity trap occurs when the demand function for money becomes infinitely elastic which may happen at a nonzero interest rate [Blinder 2010]. Regardless of the definition, if a liquidity trap occurs, the problem is that the nominal interest rate becomes stuck as it cannot be lowered from the lower bound.

To see how a liquidity trap comes into existence the Fisher principle is presented. An obvious presumption is that aggregate demand in the economy affects both real interest rates (r) and nominal interest rates (i). The Fisher equation simply states the real interest rate to be equal with the nominal interest rate less inflation expectations as:

$$r = i - \pi^e. \tag{68}$$

Consequently, in the occurrence of inflation, future payments are made in money worth less than today [Burda and Wyplosz 2009]. In the light of a liquidity trap, let it be considered that the nominal interest rate is zero and the economy is in deep recession. The central bank desires to push the real interest rate down to stimulate the economy but the real interest rate remains stuck as $i = 0$ and $-\pi^e$ is very small or possibly even positive (in case of deflation) [Blinder 2010].

The conventional monetary policy was shown in chapter 3 to be powerless in the zero-interest rate environment, particularly if the inflation expectations are low. Another problem associated with the liquidity trap is that the economy is satiated with liquidity and nobody is willing to lend, as cash in fact pays better interest [Svensson 2003].

A liquidity trap associated with prolonged deflation and recession has severe consequences for the economy. Svensson (2003) describes the consequences briefly and comprehensively:

> "*The real value of nominal debt rises, which may cause bankruptcies for indebted firms and households and a fall in asset prices. Commercial banks' balance sheets deteriorate when collateral loses value and loans turn bad, and financial instability may threaten. Unemployment may rise, and if nominal wages are rigid downward, deflation means that real wages do not fall, but increase, further increasing unemployment.*"

This kind of self-fulfilling downward spiral is very undesirable and several possible options to escape a liquidity trap are introduced next.

4.2 An escape plan

This sub-section considers some practical solutions in order to escape a liquidity trap. It is indeed possible to exit the trap, however, it may take some time. Japan is an example of this and has been recovering and finding its way free from a liquidity trap since 1990s [Svensson 2003]. The key thing in escaping a trap is the public's *future* inflation expectations: it is desired that they ascend. The ascending of expectations brings the real interest rate down as the Fisher equation implies.

The public's future inflation expectations must be manipulated. The problem is that even if the central bank promises to set a higher inflation target, the public may doubt the central bank's ability or will to achieve that rate in the future. Instead, the public may think that the central bank will renege on its promise as soon as the trap is escaped. [Svensson 2003].

Considering rational expectations and a potential equilibrium, multiple equilibria exist, as the public may be pessimistic or optimistic and the central bank may or may not keep its promise. The best possible rational expectations equilibrium is on in which the central bank keeps its promise for higher inflation in the future and the public has faith in that (i.e. is optimistic). In this equilibrium, the central bank will keep the nominal interest rate at zero for some period even after the recession is turned. In addition to the importance of the public's future inflation expectations, another key factor is the central bank's ability and desire to show *commitment*. Otherwise the public's inflation expectations remain low and the recession will be prolonged. [Svensson 2003].

4.2.1 Positive inflation target or a price level target path

One option to create higher expectations is to announce a positive inflation or price level target path, meaning that the central bank overshoots its normal inflation target for a few years with some commitment mechanisms such as published inflation forecasts or transparent inflation reports. In other words, the central bank is credibly irresponsible as Krugman (1998) states. A practical difference in inflation target or price level target path is that under the price level target path, lower inflation in one year must be counterbalanced by higher inflation rates in future years in order to stay on the desired price level path. If the central bank has an inflation target path instead, and if it misses the target in one year, the inflation target is still the same for the next years. Thus, a credible price level target has desirable effects on longer term inflation expectations and it is better as it does not disregard past misses. [Svensson 2003]. To improve credibility, a price level target is recommended for the central bank to follow, before the zero lower bound and liquidity trap occurs [Eggertsson and Woodford 2003]. However, the expansionary effect of the inflation target or price level target path on the real interest rate occur as long as the public sees the target to be credible [Svensson 2003].

4.2.2 Expanding the monetary base

The central bank's expansion of the monetary base has been touched on previously in this thesis. If the central bank chooses to expand monetary base, a question is, whether there is any reason to believe that money supply will be increased also in the future. Another factor is that, at some point, the expansion may turn from deflation to hyperinflation. It is hard to know how much expansion is needed to force inflation (expectations) to take off. [Svensson 2003].

This option is credible only if its permanent. However, it is obvious that the monetary base must contract at some point once the liquidity trap has been escaped. Therefore, a promise to never reduce the monetary base in the future is not credible and a promise to reduce it less than otherwise is a very complex issue. Thus, the sole monetary expansion will not take the economy out from the liquidity trap. [Svensson 2003].

4.2.3 Long-term interest rates

Long-term real interest rates affect consumption and investment decisions in the economy, and thus a reduction in long-term nominal interest rates may be beneficial in order to escape the liquidity trap. In this case the following type of open market operations is possible: the central bank promises to buy any amount of government bonds up to a particular maturity with certain low or zero interest rate that it states before the issuance of the operation. This may be slightly problematic as it is difficult to estimate the term premium of various bonds and their substitutability with each other. An appropriate size of the market operation is almost impossible to determine. In any case, it is unlikely that such market operation alone will provide enough stimulus to the economy and it is likely that the real interest rate stays too high. [Svensson 2003].

4.2.4 A tax on money

An interesting and very unorthodox way in escaping a liquidity trap is taxing money, which has been suggested at least by [Goodfriend 2000] and [Buiter and Panigirtzoglou 2000]. By setting a tax on money the central bank allows nominal interest rate to be negative and thus the real interest rate will be pushed down. Technically, it is possible to tax money, especially the electric money and bank reserves but in terms of hard cash it may be too complicated and inconvenient as some notes of the same denomination will be traded at different discounts. [Svensson 2003].

4.2.5 Fiscal policy

Fiscal policy is a natural policy option when escaping a liquidity trap but its usefulness is a bit questionable. The level of government debt plays a role here: if it is initially high, the public may anticipate that taxes will be increased or some social benefits may be cut in the future [Svensson 2003]. As Kanniainen (2014) aptly reminds, a public debt is a transferred tax that will be paid by future generations. Initial high public debt leads the public to save more and consume less, which in turn may dampen impacts of the expansionary fiscal policy [Svensson 2003].

The public may also anticipate that increased fiscal deficits will be financed by the central bank[6]. This probably stimulates inflation expectations but as Japan's example proves; as a consequence of expansionary fiscal policy only the government debt may dramatically increase while inflation expectations remain persistently low. Another fiscal policy option is to adjust taxes, such as value added tax, investment tax, income tax and corporate tax. By adjusting taxes the government can affect the after-tax real interest rate but this option has also the same credibility and anticipation issues, which depend on whether or not the tax changes are fully financed and how permanent they are. [Svensson 2003].

4.2.6 Currency depreciation

Currency Depreciation boosts economy by improving export conditions, and simultaneously, as import prices increase it impacts positively on inflation expectations. The central bank can manipulate the exchange rate, and by pegging[7] the exchange rate at some depreciated rate credibly, it may demonstrate commitment to a higher future price level and thereby desirably affect long-term inflation expectations. If the central bank is succeeding, the higher future price level expectations result in current depreciation of the currency and the economy gets stimulated and may be pulled out of the liquidity trap. The idea is the same as in the price level target path, i.e. to demonstrate commitment credibly to create a certain depreciating path for the exchange rate. [Svensson 2003].

In an open and global economy currency depreciation may not be easy; in particular, all big economies cannot depreciate against each other at the same time. Depreciation always has a negative impact on a trading partner and thus "competitive devaluation" or "beggar-thy-neighbor policy" has always

[6] A central bank's mandate may disable this if monetary finance is not allowed

[7] Svensson suggests the following crawling peg: *"a new high initial exchange rate and the gradual fall over time of the exchange rate at a fixed rate approximately equal to the average foreign interest rate"*. See more detail in [Svensson 2003].

some constraints. The proportional size of exports and imports of competitive economies affect also the impact of the currency depreciation. These issues are taken into consideration by Svensson (2003), but he also reminds that any succeeding expansionary monetary policy action will anyways lead to currency depreciation, and thus it is nonsense to oppose a currency depreciation per se as a starting operation to escape the liquidity trap. The currency depreciation is but one option in reaching higher inflation expectations, as are the other options discussed in this subsection. [Svensson 2003].

4.2.7 The elements of the exit

Three basic elements of successfully escaping the liquidity trap can be listed on the basis of the previous discussion. First of all, (1) the central bank must be committed to a higher future price level, secondly (2) the central bank must act concretely to demonstrate that particular commitment, and finally (3) the central bank must have an exit strategy that specifies the returning back to the normal state. That strategy must also include the definition of "normal state". [Svensson 2003].

On the basis of these three elements, Svensson proposed "a Foolproof Way" to escape a liquidity trap for Japan in the beginning of 2000s' which consisted of announcing and implementing three measures: "*1) an upward-sloping price-level target path, starting above the current price level by a price gap to undo; 2) a depreciation and a crawling peg of the currency; and 3) an exit strategy in the form of the abandonment of the peg in favor of inflation or price-level targeting when the price-level target path has been reached.*" [Svensson 2003].

Note, that Svensson's proposal to set a crawling peg of the currency is just the central bank's way of demonstrating commitment to a higher future price level. It will be abandoned as soon as the desired price-level target path has been reached. It helps to reach higher inflation expectations, and the intention is not to control the exchange rate. Ideally, the exchange rate is left to be determined by the markets.

5 Conclusions

Monetary policy has been rethought in this thesis dividing the timeframe into two periods in relation to the global financial crisis. This rethinking has leaned on three different theoretical and quantitative models. In the pre-crisis context it was found that the coordination of monetary and fiscal policies play a key role considering a central bank's possibilities to control or affect inflation. In particular it became apparent that if fiscal policy dominates monetary policy, and explicitly determines monetary policy then monetary policy will become unable, even temporarily, to control inflation. Paradoxically, conducting loose monetary policy was found to be Pareto-improvement in fighting current inflation.

In examining the RBC-model of Farmer (2012) in the pre-crisis context, it was illustrated that a central bank is able to control inflation (and expectations) by choosing and credibly following a policy rule. By choosing a policy rule the central bank simultaneously determines a steady state inflation rate and the real rates of return will adjust through a change in nominal interest rate, rather than through a change in inflation. Moreover, the particular RBC-model was found to explain relatively well the history of inflation in the USA from post-WWII to the end of the period of Great Moderation.

The post crisis section began with the examination of the central and commercial banks' balance sheets. It was observed that deposits and reserves have a crucial role in the monetary system. It was also found that the central bank is in control of the quantity of reserves, as it supplies the necessary amount of these to the economy. This control is done via asset purchases and sales. However, it was noted to that commercial banks are unable to lend out any excessive reserves they might have, except in the interbank market. Instead, it was found that commercial banks are able to create loans out of nothing, due to the fact that loans and deposits are counter-items in their balance sheets. This thesis defended the representation of credit creation by Werner (2005) rather than the classic economics textbook representation, which sees credit creation as merely intermediating already existing purchase power.

The subsequent anatomy of quantitative easing revealed that, even if the zero lower bound on the nominal interest rate is binding and further causing conventional open market operations to be ineffective, the central bank may stimulate the economy and encourage commercial banks in lending via asset-purchase-programs. The examination of the RBC-model by Farmer (2012) supported this. Moreover the RBC-model demonstrated that via unconventional open market operations (asset-purchase-programs) the central bank extends credit to the economy, provides more liquid assets to the private sector in the form of reserves and government debt, and is also able to show commitment to change to another monetary policy rule that is associated with higher inflation expectations. Evidence from the swap market data was founded to support the claim that long-term asset purchases and thereby expanded central bank balance sheets succeeded in increasing inflation expectations in the USA and in the UK in the midst of the crisis.

Chapter 3 also introduced a state-of-the-art type of DSGE-model by Gertler and Karadi (2011), which mimicked some features that were associated with the crisis. A credit policy central bank intervention was found to be beneficial in a crisis situation regardless of whether the zero lower bound binds or not. However, if the zero lower bound does bind, the intervention is even more desired. The large increase of the central bank's balance sheet improved inflation expectations and yet the inflation rate remained relatively stable. Yet, as the crisis situation ends and private financial intermediaries slowly become recapitalized the benefits of unconventional monetary policy diminish.

Chapter 4 introduced an unwelcome liquidity trap situation, where the nominal interest rate hits the (zero) lower bound and cannot be lowered further. Consequently, in a case of recession, the real interest term remains too high as the difference between the nominal interest rate and inflation expectations is close to zero or even positive. In addition, Chapter 4 provided options in order to escape the liquidity trap. Three key components for a successful exit were: (1) commitment by a central bank to a higher, future price level, (2) a concrete policy action to prove this commitment and (3) a clear exit strategy that specifies the return to normal, which may be different to what was initially deemed normal.

In the aftermath of the crisis, of which the end may be still yet to unfold, unconventional monetary policy has been the normal state. The coming years will undoubtedly reveal what the new normal of future monetary policy looks like and also how the policy evolves and adapts to this new norm.

A day may come when higher inflation expectations occur. A day may come when lower inflation expectations are desired.

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